THE BRAZILIAN NATIONAL ALCOHOL PROGRAMME:

A TECHNOLOGICAL PERSPECTIVE

FRANCISCO ROSILLO CALLE

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ABSTRACT

This thesis analyses the Brazilian alcohol programme, the "ProAlcool". It concerns, in the main, with the technological components of the production/utilisation of industrial alcohols by fermentation, for use as fuels and chemical feedstocks. It also considers socioeconomic issues, criticisms, achievements and failures of the programme. It is concerned with bioenergy technology and the possible role of the ProAlcool within a wider Third World context; the need to phase in new fuels before the old ones run out; the importance of renewables energy sources. The importance of bioenergy stems from the fact that for many LDCs it is the best hope for achieving greater economic and energy independence.

Unlike the industrial countries, in the LDCs the energy crisis continue unabated, due to the combination of economic and social problems, with many spending over 50% of their export earnings in oil imports. The ProAlcool contribution to bioenergy is due to the fact that for the first time bioenergy is being used in a large industrial scale for modern use of energy; the 95% of all passenger cars (c. 2 million) and the 57% of the light commercial vehicles now powered by alcohol, are the best testimony. Significant technological advances has already been made in many fronts. The programme can serve as a "school" for other countries willing to take a similar path.

The ProAlcool has been very successful in the production/utilisation of ethanol; it has a significant impact in agriculture within the sugarcane growing areas; in the adaptation of the Otto-Cycle engines to alcohols and in improving and developing alcoholchemical processes. But it was also found that Brazil does not have a technological leadership in alcohol technology. Rather its advantage stems from acummulated historical experience and early start which have given Brazilian firms a headstart advantage.

Technological advances have not been matched in the same level in the social front. Economic rather than social development has been the core of government policy for the past 50 years. The food problem has its roots in the agricultural policy not in the ProAlcool, which is based more on "trial and error" strategy. Many of the criticisms of the programme do not address the fundamental questions.

KEYWORDS: Bioenergy, Industrial alcohols, Fermentation, Alcohol fuels, Ethanolchemistry.

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NOTE

The use of the dollar symbol ($) denotes USA dollar unless otherwise indicated, namely the Brazilian Cruziro denoted as Cr$. The word P.N.A. and ProAlcool are used interchangeably; the same applies to ethanol and alcohol. In Brazil alcohol, rather than ethanol, is commonly used.

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ABBREVIATIONS

ABDIB	Associação Brasileira para o Desenvoluimento da Indústria de Base/Brazilian Association for the Development of Basic Industries
ABIQUIM	Associação Brasileira da Indústria Químmica e de Produtos Derivados/Brazilian Association of Chemical Industries
ACIESP	Academia de Ciencias de Sao Paulo/Academy of Sciences of the State of São Paulo
ANFAVEA	Associação Nacional dos Fabricantes de Vehiculos Automotores/Brasilian Association of the Automobile Industry
B.d.p.e.	barrel: day petrol equivalent
BIRD	Banco Interamericano para la Reconstrucción y el Desarrollo/Iteramerican Bank for Reconstruction and Development
CAPES	Companhia de Aperfeiçôamento de Pessôal de Ensino Superior/Company for Training of Higher Education Personnel
CAT	Centros de Assistencia Técnica/Technical Support Centres
CENA	Centro Nuclear na Agricultural/Agricultural Nuclear Centre
CENAL	Commissão Executiva Nacional de Alcool/National Executive Alcohol Commission
CEPED	Centro de Pesguisas & Desenvolvimento/R+D Centre
CESP	Companhia Energética de São Paulo/Energy Company of the State of Sao Paulo
CETEC	Fundação Centro Tecnológico Minas Gerais/Technology Centre of Minas Gerais
CETESB	Companhia de Tecnologia de Saneamento Ambiental/Technological Environmental Company
C.I.F.	Cost-Insurance and Freight
CNE	Comissão Nacional de Energia/National Energy Council
CNP	Conselho Nacional do Petroleo/National Petroleum Council
CNPg	Conselho Nacional de Desenvolvimento Cientifico & Tecnològico/Science Engineering Research Council
CTA	Centro Técnico Aeroespacial/Airspace Technical Centre
CTI	Companhia de Tecnologia Industrial/Company of Industrial Technology
ECLA/CEPAL	Economic Commission for Latin America

EMBRAPA	Empresa Brasileira de Pesquisas Agropecuarias/Brazilian Agricultural Research Corporation
ESALQ	Escola Superior de Agricultura Luis de Queiroz/Higher School of Agriculture "Luis de Queiroz"
FAPES	Fundação de Amparo a Pesquisa de São Paulo/Foundation for the Support of Research of the State of Sào Paulo
FIBGE	Fundação Instituto Brasileiro de Geografia e Estatística/Brazilian Geography and Statistics Institute
FINEP	Financiadora de Estudos e Projetos/Studies and Projects Fundings Agency
FTI	Fundação Tecnologia Industrial/Foundation of Industrial Technology
GDP	Gross Domestic Product
GMB	General Motors do Brazil
GO	Goias
IAA	Instituto de Açúcar e de Alcool/Sugar and Alcohol Institute
IAC	Instituto Agronómico de Compinas/Compinas Agromony Institute
IIICBE	III Congreso Brasileiro de Energial/3rd Brazilian Energy Congress
IMF	International Monetary Fund
INT	Instituto Nacional de Tecnologia/National Institute of Technology
ISI	Import Substitution Industrialisation
l	Litre
LDCS	Less Developed Countries (hereafter also as Developing Countries, Third World and the South)
LPG	Liquidfied Petroleum Gas
M^3	Cubic metre
MA	Ministerio da Agricultura/Ministry of Agriculture
MBB	Mercedes-Benz do Brazil
M.b.p.d.	Million barrel per day
MEB	Modelo Energético Brasileiro/Brazilian Energy Model
MG	Minas Gerais

MIC	Ministerio da Industria e de Comercio/Ministry of Trade and Industry
MME	Ministerio das Minas e Energia/Ministry of Mines and Energy
MNCs	Multinational Corporations
MON	Motor Octane Number
M.t.p.e	Million ton petrol equivalent
NIEO	New International Economic Order
PADCT	Programa de Assintencia para O Desenvolvimento da Ciencia Tecnologia/Programme for the support in the Development of Science and Technology
PBDCT	Plan Básico de Desenvolvimento Científico & Tecnológico/Basic Plan for Scientific and Technological Development
PE	Pernambuco
PNA	Programa Nacional do Alcool/National Alcohol Programme
PNEF	Programa Nacional de Energia Forestal/National Energy Forestry Programme
PNPE	Programa Nacional de Pesquisas Energéticas/National Energy Research Programme
PPDTB	Programa de Pesquisa & Desenvolvimento da Biomassa/Biomass R+D Technology Programme
PRONAB	Programa Nacional de Biotechnologia/National Biotechnology Programme
PTE	Programa Tecnológico do Etanol/Ethanol Technology Programme
R.B.T	Revista Brasileira de Tecnologia/Brazilian Journal of Technology
R&D	Research Development
RON	Research Octane Number
SEPLAN	Secretaria de Planejamento da Presidencia da República/Planning Secretariat of the Presidency of the Republic
SNDCT	Sistema Nacional de Desenvolvimento Cientifico & Tecnológico/National System for Scientific and Technological Development
SP	São Paulo

S&T	Science and Technology
STAB	Sociedade dos Técnicos Açucareiros e Alcooleiros de Brasil/Society of the Sugar and Alcohol Technologists
RS	Rio Grahde do Sul
RJ	Rio de Janeiro
THFN	Nitrate Tetrahydrofurfuryl
UFRJ	Universidade Federal RJ/Federal University RJ
UNICAMP	Universidade de Campinas/Campinas University
VWB	Volkswagen do Brazil
W/v	Weight by Volume

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GENERAL INTRODUCTION

Since 1973 energy has probably been the most intensively studied of all subjects among governments, business concerns and academics. The energy events of the 1970s caused great upheavals in world energy markets. This led to two major changes: (i) the "conservation revolution" that no energy scenario can ignore; (ii) a hectic search for new energy sources, notably renewables.[1] The search for alternatives to oil has led many nations, both in the industrial countries, and Less Developed Countries (LDCs) , to intensify their efforts particularly in the direction of research activities. The North, to maintain their standards of living and level of achievement; the South to solve their industrial, social and economic problems.

However, just over a decade after the energy crisis, the world energy situation is paradoxical. In the LDCs - with all the differences on research endowment and levels of development that this entails, the energy situation has worsened dramatically, despite the fall in oil prices. Since oil imports are paid in dollars, the combination of a strong dollar and high interest rates, (many countries buy their oil on borrowed money) has put the oil import bill at an all-time high. Many LDCs are paying over 50% of their total export earnings to buy imported oil. 80 of the 112 developing countries do not have any oil. In the industrial countries, on the other hand, oil import costs have declined. This is due to a combination of factors: (i) falling demand due to the economic recession; (ii) changes in industrial consumption of energy (e.g. closing down of many energy intensive industries such as steel); (iii) conservation measures, which have been far more effective than in the LDCs.[2] This situation is creating once more a dangerous degree of self-complacency in many industrial countries, with R&D in energy taking second place, particularly other new forms of energy.

Therefore, whilst in the industrial countries the energy problem may have seemed to subside for the time being, in the LDCs the crisis continues unabated, because the lack of financial resources, skills, the problem of adaptation to permanently higher energy prices, and to their traditional and commercial energy sector, etc.

Energy, like food, is essential to all human activity. Energy scarcity is as bad as food scarcity. But with energy as with food, there are the "haves" and the "have nots". Lack of access to a reasonable amount of energy limits the living standards and quality of life of millions throughout the world. For thousands of years, human development has been dependent upon harnessing sources of energy that are additional to man and animal labour. But the modern man's intensive use of energy is out of proportion to his real needs.

Our highly industrial urbanized society is sustained by massive quantities of energy in the home, factories, offices, etc. Our energy-intensive way of life tends to be copied by the LDCs' ruling elites eager to emulate Western consumption patterns. It is, generally, the elite and urban middle classes who participate in the modern consumer society, based on this high energy consumption. The poor and the rural population hardly benefit from massive investment in energy intensive projects - e.g. the Itaipu hydroelectricity dam and the Angra nuclear plant in Brazil are two classical examples.

The energy problem cannot, obviously, be resolved by energy measures alone. More fundamental questions and political priorities are at issue. But energy strategies which use more local resources and less capital intensive technologies are urgently needed. A common need to many LDCs, e.g. is to establish an indigeneous technological capability of which the development of technology to harness renewable energy sources could be particularly important, because many of these technologies are less costly and sophisticated.

Renewables, which are abundant and inexhaustable,[3] despite the contempt of the conventional energy agencies, are becoming increasingly important. Over a decade of gloomy bureaucratic forecasts, renewable energy is being chosen around the globe, together with energy conservation. More than a dozen renewable energy sources have been explored and many harnessed. The progress of the last years marks a coming of age for renewable energy.[4]

Bioenergy is one of the primary sources of fuel for millions of people. It is also an exceedingly promising alternative energy source for supplying modern sector needs of LDCs. Brazil's ProAlcool is a case in point. This is of extreme importance because traditional use of biofuels cannot provide modern needs of energy - e.g. irrigation pumps, T.V., refrigeration, etc. The importance of the Brazilian alcohol programme stems from the fact that it is using biomass in a modern industrial scale to provide much needed liquid fuels. Biomass[5] has served the human race from the down of history until the present day, and is the most abundant source of energy.[6] What eclipsed simply biomass as the modern man's main source of energy was the discovery that mother nature has provided solar energy in even more concentrated forms - the fossil fuels. These were very convenient fuels and also very cheap.

A challenge facing science is to develop biofuels that enhance rather than erode the environment and which improve the quality of life in the world. No one has yet come up with a practical biomass system that can effort the convenience of hydrocarbon fuels. But science can do a great deal to improve the efficiency of Biomass energy.

The key to a viable renewable energy-based future is that the world finds a means to make the transition gradually, phasing in new fuels before the old ones run out and simultaneously reshaping economies and societies.[7] Within this context Brazilian achievements and failures are of the greatest interest. The ProAlcool can serve as a "school" for other countries. It has made significant technological contributions to bioenergy technology, especially that concerned with the production and utilization of industrial alcohols.[8] Brazil has shown a readiness to share its know-how and experience with other countries willing to follow a similar path.

This research is, therefore, important for a number of reasons. (i) Alternative energy sources are too easily dismissed as being of little importance. Brazilian experience demonstrates that it is not the case. (ii) The knowledge and understanding of the ProAlcool outside Brazil is poor, incomplete, inaccurate and contradictory particularly with regard to its technological achievements. Brazil is playing a leading role in the path toward a new energy era, so far as renewable energy is concerned. This is not always recognized outside Brazil. It is important to demonstrate such achievements and also its failures. (iii) There is a growing interest in alcohol fuels, in the industrial countries due to the growing demand for unleaded gasoline, and in the LDCs because foreign exchange considerations, the possibility to produce high cost energy locally, political etc. In Brazil 95% of all passenger cars and over 57% of all light vehicles and over 20% of heavy commercial vehicles, in 1984 run on alcohol. Surely such achievement and experience is of great interest to others. There are important lessons to be learned and know-how which can be shared from such an experiment, which is quite unique and unparalled at a national scale.

On the other end of the scale, there have been many statements which in my view "overstate" the success of the ProAlcool. An objective of this research is to assess some of these claims. A programme of the complexity and scope as the ProAlcool, cannot realistically be analyzed in all its facets. Hence the main theme of this research is to analyze, in the main, the technical components of the alcohol programme, for reasons stated in section 1.1.

Therefore the structure of this thesis is as follows:

Chapter 1 commences by looking at the possible theoretical thinking behind the programme; considers the thesis objectives and methodology, institutional barriers to the development of new energy sources, notably biomass. It analyzes briefly, Brazil's drive to industrialization (this led to greater energy and technology dependence), and the scientific and technological capabilities; the possible contribution of biotechnology; it describes the main energy trends of the decade, and the self-sufficiency energy scenario.

Chapter 2 addresses five main aspects related to the ProAlcool: the agricultural sector, underlying reasons for the creation of the alcohol programme, productive structure of the alcohol sector, production scenarios, and R&D related to the programme.

Chapter 3 concentrates on feedstock production - sugarcane, cassava, sorghum, forestry and vegetable oils - problems and perspectives.

Chapter 4 discusses the alcohol equipment sector, considers the historical evolution of this industry, plant capacity, market potential and major innovations.

Chapter 5 analyzes process technology in more detail, particularly fermentation technology but also extraction, distillation, stillage recovery, cassava and cellulosic technology.

Chapter 6 describes alcohol fuels, the main technological innovation of the alcohol-powered vehicles, main alternatives under consideration to solve the diesel problem, and the use of alcohol fuels in trucks and tractors.

Chapter 7 discusses the ethanol-based chemical industry, its historical evolution, installed capacity and processes; political and economic issues, and specialty chemicals.

Chapter 8 assesses the main socioeconomic problems, political issues, energy balance, environmental problems, food vs. fuel, employment and criticisms of the ProAlcool.

Chapter 9 contains the main conclusions and policy recommendations. It also describes some obstacles to energy transition, challenges and technical and social contributions of the ProAlcool.

Finally, Appendix 1 lists the main research centres, distillery equipment manufacturers, labs, etc. visited as part of the field work in Brazil.

CHAPTER 1

THEORY AND POLICY CONSIDERATIONS

Introduction

On 13 November 1975 the Brazilian government created, by the Decree No.75693, "O Programa Nacional do Alcool - P.N.A." (The National Alcohol Programme). More widely known as ProAlcool. Subsequently, restructured and consolidated by the Decrees No.83700 of 15 July 1979 and No.80796 of 18 November of 1979, to accommodate the new energy policy objectives after the second oil shock.

The ProAlcool represents a remarkable and unique experiment on renewable energy. It can be regarded as one of the most important testing grounds for the development of biomass-related technology, particularly in the production and utilization of industrial alcohols by fermentation. It is also one of the best guarantees that the renewable energy technology will become increasingly part of the economic mainstream. The ProAlcool is a renewable energy programme without parallel in the world, at a national scale, and whose repercussions are bound to be felt beyond Brazil's borders. The programme has received much worldwide attention and also criticism.

The P.N.A., in its original conception however, did not appear to represent any radical solution to the energy crisis. It should rather be regarded as one of the several alternatives under consideration to reduce Brazil's dependence on oil imports. Brazil, more than any other developing country, epitomized the oil age. Since the time of the Kubisckek government in the 1950s, the country's entire industrial and transportation infrastructure had been developed on the assumption of cheap petroleum.

Therefore, after the oil shock of 1973 the country was facing an acute energy dependence and worsening balance of payments. To make matters worse this coincided with a near collapse of sugar prices in the international market. The collapse of sugarcane, a major commodity crop, would have caused serious social and economic problems.

At the same time President Geisel, the main political architect of the PNA, who was previously Managing-Director of Petrobra (the State oil monopoly) was all too aware of Brazil's vulnerability to oil supplies. This vulnerability was also aggravated by the fact that extensive geological surveys had shown that oil reserves in Brazil were very small in consideration to the potential demand of the Brazilian market.[1]

The ProAlcool has strong nationalistic overtones, for its pioneering scale and because it is one of the few successful Brazilian projects.[2] No doubt the military played a key role in setting up the programme and its posterior consolidation. But such military participation is not unique to the ProAlcool, but a natural consequence of the Armed Forces' historical involvement in the Brazilian industrialization process.

The nationalist elements within the Armed Forces, the so-called "tenentes" formed the main pressure group, in the 1930s, behind the setting up of the steel industry; a major step in the industrialization process. From 1937 almost all state sponsored industrialization in Brazil took place under the military auspices.[3] A further example of direct military intervention was oil exploration. Oil was regarded by the military as a strategic commodity and hence they were instrumental in the creation of the CNP (National Petroleum Council), and later the "Petroleo Brasileiro", popularly known as Petrobras.

Since the 1964 coup, such involvement in all branches of the economy grew faster than ever, to a point that the State sector is the most powerful economic force in Brazil today.[4] In the mid 1970s a "new class" of military and civilian technocrats and these giant state enterprises were the central focus of power. Thus the State involvement in the economy was such that industrialists feared, during the economic crisis of the mid 1970s, that in order to protect its own fiefdoms, the government might have taken protective action - e.g. restricting the remission of profits to parent companies abroad. This would have clearly been detrimental to the large private industrial groups, and therefore a vigorous campaign was launched, not against the then President Geisel, but against state intervention in the economy.

This takes us to an important characteristic of the ProAlcool: that it remained in private hands and 100% under Brazilian control. That seems to have been the consequence of the strong opposition of industrialists, particularly the sugarcane lobby, who feared that the alcohol programme would become just another state enterprise. A second element appears to have been the division within the armed forces.

Contrary to popular belief, the regime was far from being monolithic in their economic thinking. They agreed, e.g. that the main priorities were to reduce inflation, to introduce wages control, and to create the climax for foreign investment. But when it came to the political means whereby the economic strategy was to be implemented, the political model to be adapted by the regime, serious differences emerged.

The military were divided into two main factions (i) the "Sobornnist",[5] whose main exponent was President Castello Branco, fiercely opposed to nationalists and left-wing positions; (ii) the so-called "Linha dura" (or hard-liners) who were for the most part ordinary soldiers strongly anti-communist, inflexible and strongly nationalistic and much less enthusiastic about foreign capital.

The extent to which these factions influenced the policy on the ProAlcool, is not too clear. Such political analysis is beyond the scope of this thesis. However there was intense infighting within the State bureaucracy for the control of the programme, as illustrated in 2.2. Although the State control the programme through a purchasing-of-alcohol policy, to brand the ProAlcool as the "child of the military regime" is a wrong conception in my view. Powerful socioeconomic groups have played a prominent role.

Neither does it appear that the military have a clear theoretical framework, but rather a pragmatic approach, which I would describe as "learning by doing" and "trial and error". Rather, it should be seen within an overall national energy strategy (see section 1.6).

However, a School of Thought, which has had a great influence in Latin America, is the Dependency School of Thought.[6] This school has devoted a great attention to the analysis of the internal problem of economic development. The Import Substitution Industrialization (ISI) strategy, so prominent in the industrialization policy followed by Brazil, particularly since the 1950s, emanated from this school.

Another important influence was the "New International Economic Order" (NIEO), articulated in the mid 1970s, and also related to the breakthrough of the dependency paradigm.[7] The NIEO called for important structural changes in the world industry, because (i) new factors of technological progress; (ii) contradiction of technological and educational developments; (iii) new forms of raw materials and energy supply.

The concept "technological dependence"[8] also gained wide acceptability and introduced a new element: the belief that indigenous Science and Technology (S&T) could provide many solutions to development problems. This concept also led to the Technological Self-Reliance (TSR)[9] which called for the creation and establishment of capabilities for management of scientific and technological knowledge in Developing Countries. Brazil, whose process of industrialization has led to an increasing technological dependence, was one of the first developing countries to show a strong interest on S&T (see section 1.5).

No doubt that these new emerging concepts might have been very much in mind, or have had some kind of influence, in the thinking of those who created the P.N.A.

1.1 Thesis Objectives

The P.N.A. was set up with a multi-purpose in mind. The broad objectives can be summarized as follows.

(i) To lessen Brazil's external vulnerability to oil supply.

(ii) To increase energy independence through the utilization of renewable domestic resources.

(iii) To develop equipment and process technology for the production and utilization of industrial alcohols.

(iv) To achieve greater socioeconomic and regional equality.

This thesis would be concerned in the main, with the technical components of both the production and utilization of industrial alcohols. This is because the technological aspects of the ProAlcool are less well known outside Brazil. Secondly because the programme has wide technological implications to other countries with similar characteristics to Brazil. This technology is evolving very rapidly and the Brazilians are leading in certain ways. The third reason is because non-technical aspects - e.g. social, are very specific to place and circumstances and therefore a detailed study of such nature would not realistically be possible. I am aware of the fact that non-technical and institutional impediments to biomass-related energy systems are very serious indeed. I propose, therefore, to assess the most important criticisms of the ProAlcool too. In addition, I propose to assess the following statements:

> "The hard and difficult work already done takes us a step nearer to the much wanted energy independence; we need a few more years, but we are already sure that such energy autonomy would be achieved".
> (Joao Batista Figuereido, President of the Republic of Brazil)[10]

> "Brazil possesses a complete technological dominance in all phases of alcohol production, and an internationally competitive alcohol capital

goods sector."

(Camilo Penna, Secretary of State for Trade and Industry)[11]

"Brazil has successfully confronted the world dispute for the development of technology in large-scale to replace fossil fuel energy by alternative energy technology."

(Camilo Penna, Secretary of State for Trade and Industry)[12]

"Brazil can become a large supplier of alcohol chemical products and of a sophisticated alcohol chemistry technology."

(Paulo Cunha, Managing- Director of Oxiteno)[13]

"The country who has both energy and technological autonomy, will be able to dictate its own development paths....)."

(Cesar Cals de Oliveira, Secretary of State for Mines and Energy)[14]

Therefore I propose: (i) to assess the state-of-the-art of production and utilization of industrial alcohols in Brazil; (ii) to assess the extent to which Brazilians can/are achieve/ing such objectives; (iii) to assess the above statements on the ProAlcool; (iv) to assess the main criticisms and obstacles; (v) to assess the scientific and technological contributions of the ProAlcool and the possible lessons to be learned.

At this point I should define some technological concepts. I would like to borrow Green and Morphet definitions of: <u>TECHNOLOGY: as</u>

"the technology of a particular process or industry is the assemblage of all the craft, empirical and rational knowledge by which the techniques of that process or industry are understood and operated. An advance in technology, then will involve the generation of new knowledge and the addition of <u>new techniques</u> to a set already available.(..)"

"Technique: the interaction of person(s)/tool or machine/object which defines a "way of doing" a particular task."

"Technological innovations: when industry either produces goods which consumers prefer (or deemed or persuaded to prefer), or produces goods more efficiently and at lower cost."[15]

1.2 Methodology

I have used two main methods in my research. Firstly I did an extensive literature review both in Britain and Brazil. This allowed me to identify the main research activities, problems, and difficulties; and also research in specific areas. Because the large number of topics covered, the literature survey was an extensive one.

Secondly, was field work. This consisted of visiting laboratories, (e.g. sugarcane), government and private research institutions; alcohol equipment manufacturers; alcohol distilleries, pilot plants, etc. This allowed me ample opportunities to gain first hand knowledge of specific areas, and to talk directly and interview experts involved in specific projects.

Thirdly, I should mention a number of difficulties I encountered with my research. With regard to the literature review, it was first a handicap because the difficulties in finding data on specific topics of the ProAlcool. With regard to Brazil, it is true that there exist a very extensive literature, but few specialized journals, which in most cases are the official publications of the sugar and alcohol industry. It also led to conflicting views and evidence. This calls for caution when interpreting data.

Data collection, on the whole, presented special difficulties in a country as large as Brazil. Usually means travelling upon long distances, and not very good communications (if one excludes the Sao Paulo State). A further difficulty, which is a typical Brazilian problem, is the lack of, or poor communication between research institutions and individual researchers. This communication barrier, which often results in research duplication, is something which the outsider must get accustomed to.

Finally, these are two additional factors which I should like to bring attention to. One was my academic base at Campinas University (SP.), Faculty of Agriculture and Food Technology. This university is a leading centre on biomass research, and hence I was able to benefit from many informal talks with many academics. A second factor which allowed me to gain much insight into the ProAlcool was a number of conferences and courses which I was able to attend during my two visits to Brazil.

Finally in this chapter, before considering the ProAlcool, I would highlight the more important problems, institutional barriers and challenges confronting the development of alternative energy technology, which could affect the ProAlcool in one way or another.

(i) I would consider possible energy trends, amid present uncertainty. Of particular importance are possible biomass-based developments.

(ii) Consider, briefly, Brazil's drive to industrialization, which used the automobile industry as the main spin-off force for industrial growth. This policy also led to an increasing technological and energy dependence.

(iii) To assess the technological components of the P.N.A., one must be able to glance at the scientific and technological capabilities of Brazil. I would consider science and technology capabilities, albeit briefly. Of particular interest is biotechnology, because three out of the four of the priority research areas asigned in the PRONAB (National Biotechnology Programme) relate directly to ProAlcool.

(iv) The ProAlcool should be seen, primarily, within the Brazilian energy policy scenario. I will consider the main energy trends from the 1970s, particularly the self-sufficiency energy scenario.

1.3 Energy Considerations

We are already embarked in a new energy transition era, in which the sun will play an increasing role, particularly in developing countries. Few experts will doubt that the transition has already begun, albeit there is much disagreement over how long we can expect that transition to go, in which direction and over what period of time. One thing is certain, the next energy transition would almost certainly need to be executed over a shorter period of time than any previous one.

Since the oil crisis of the 1970s, each country has been moving at different speed, and often in different directions, in the search to solve the energy problem. This will continue to be the case, if one considers the dramatically unequal endowment of renewable and non-renewable energy resources of each country. There is not a single panacea to the energy problem. Coal cannot be the alternative to oil any more than nuclear fussion or renewable energy can. The energy source of the future is clouded with uncertainty.[16]

For decades the function of the adequacy of the world's material resources to support its increasing population has generated deep divisions. The most extreme conservation and environmental advocates assert that the earth's carrying capacity has already been exceeded. Others warn that resources are being depleted at ever increasing rates, while population growth rates also remain high. In contrast some research managers argue that advances in scientific knowledge and technology offer the promise of meeting the needs of much larger population at enhanced level of living. In the end, the picture seems to reflect "either gloom nor euphoria".[17] The present energy problem is not due to lack of physical resources, but to over-dependence on very few energy sources, overconsumption and waste. In that sense the 1970s energy crisis represented a benefit and a challenge toward a more efficient use of energy. A direct consequence of such crisis was the so-called "fifth energy" or the realization of the enormous scope for energy savings, without curtailing functions.

For example, it has been estimated that the entire world could enjoy a standard of living comparable to Europe in 1975, while reducing the per capita energy use by half.[18] And in the USA, it could achieve a full employment economy, with per capita income increase of 45% over the next 25 years, whilst reducing its energy consumption by 25%.[19] The energy conservation philosophy represents a new factor in energy policy, which is unlikely to be reversed because the large saving that can be gained without much additional investment. However given the enormous vested interests one should not take for granted that the historical links between economic growth and energy demand are now broken for once and for all. If the economic revival, particularly in the industrial countries, is not accompanied by the corresponding increase in oil prices, then investment in energy savings would become less attractive.

With regard to alternative energy technologies, what Lovins calls "soft paths"[20], these are very attractive options. This is because they distribute the technical risk among many diverse low energy technologies; depend on a pluralistic choice; are more compatible with social diversity and personal freedom of choice and are more consistent with the traditional values.

But such paths face many institutional interests, and political obstacles to overcome in addition to economic ones. Many new concepts of "alternative technologies" have been developed in the North and then transferred to the South.[21] Thus it is an irony that the main opposition, to these "soft" technologies, comes from the Developing Countries. This opposition comes from both the right and left of politics.

From the right, mostly due to vested interests (e.g. large investment in traditional energy projects such as nuclear energy, coal, etc). The State bureaucracy also is unenthusiastic because this means fewer opportunities for well paid jobs in large public enterprises; and secondly because big modern investment projects are of greater propoganda importance.

The left, particularly the far left, does not like the "soft" option either for fear of technological domination. This technology is seen often as static and dissociated from modern science: As a diversionary tactic on the part of the North because it seeks to redirect significant part of scientific and technological capability of the South toward the development of these new "rural oriented" technologies, leaving the main muscle of industrial power in the hands of the MNCs. It is also seen as an evolutionary concept; slow and long-lasting change which may involve replacing revolutionary movements by the so-called "grass roots" development effort involving much lower pace of social and economic transformations, that is based in the most modern technology.[22]

There is also a general psychological predisposition with the most advanced technology "per se"; a sensitivity to differences in the level of development of productive forces between North and South, and the inclination to identify such forces with the level of technical developments; a fascination with a certain ideal pattern of a new world which under no circumstances should be inferior to the most modern achievement, including technology.[23]

Therefore this desire for "high technology" results frequently in the utilization of technology unsuitable to developing countries conditions. If we consider, e.g. the modern alcohol distilleries in Brazil, there seems to be a tendency to automatize, with high investment cost, when there is so much cheap labour available. The "soft" option also involves considerable decentralization of both ownership and control of investment and production. This limits the direct intervention of the central planning authorities, and to a certain extent, to a limitation of the power of the State. Decentralization is regarded in many developing countries as a threat to the national security.[24] Thus the introduction of such "soft" technologies would demand strong governmental support if it is to succeed.

At the same time, however, the "soft" option is nonetheless gaining ground for a number of reasons: Firstly because spectacular technological solutions (e.g. nuclear energy) have been shown to be ineffective, emphasizing the need for greater economic rationality in which energy technology has an important part to play. Secondly, because it appears increasingly clear that high energy technology is particular in becoming unworkable. Even the richest and more sophisticated countries lack the skills, industrial capacity and managerial ability to maintain such rapid expansion of high energy technology. This is a message which is slowly getting through to developing countries' bureaucracy.[25]

1.3.1 Biomass Utilization

Of all possible new developments in the alternative energy technology, the most important and promising ones, at least in the Developing Countries, are those related to biomass. In this sense the ProAlcool constitutes one of the most important and promising ground for such new developments, since biomass in one of the world's most important source of energy.

Biomass provides 14% of world primary energy, equivalent to 20×10^6 /barrel petrol equivalent per day (b.p.e.d). Two and three quarter billion people in the developing countries use biomass as their single most important source of energy. In all, 43% of all energy used in those countries comes from biomass. For some countries e.g. Nepal and Ethiopia, derive nearly all energy from biomass.[26]

But as Hall puts it, is a fallacy to think of biomass as a "traditional" fuel that is utilized only in rural areas. Biomass has important "modern" roles as a substitute for other fuels, and plays an important part in the money economy of the developing countries. And in the industrial countries biomass constitutes a sizeable proportion of energy, e.g. 17% of Sweden's energy requirements, 8% in Canada and over 4% in the USA.[27]

The development of biomass energy sources is vital to the poor countries, despite the apparent fall in oil prices. Contrary to the general belief, the cost of energy in most developing countries is at, or near all-time peaks as the softening in dollar-dominated oil prices has been offset by the strong USA dollar. The cost of crude oil (CIF) in local currency, taking into account both dollar price and exchange rate fluctuations, has increased dramatically in many countries between 1982 and 1984: 130% in Morocco, 123% in Senegal; 185% in the Philippines; 147% in Kenya; and 237% in Jamaica."[28] See also table 8.2.

There is a significant scope for the development of biomass energy systems, particularly looking at large industrial scale utilization of biomass. The renewed interest in biomass, in both North and South, have led to significant advances in crop production systems and established conversion technologies with higher efficiencies; development of new technologies; a diversification of large amounts of money for research and the initiation of a number of national programmes and many individual commercial projects.[29]

At the same time it must be recognized that many biomass developments require technical and capital inputs often beyond those available in the developing countries. In fact few developing countries appear to have the capability to implement a large biomass programme - e.g. Brazil, Argentina and South Africa. The Brazilians experience so far tends to demonstrate that: a strong industrial base, the availability of capital, the capacity to provide large technical assistance at local levels, are very important prerequisites to the success of a large biomass programme. It should also be mentioned that the ProAlcool policy was based on a simple technological development, which allowed low investment in industry and agriculture. Brazilians were also able to use their historical experience and industrial base to build on. At the same time Brazilians were able to launch a sizeable biomass R&D programme which, in my view, is financially and technically beyond the reach of most developing nations.

This situation can become serious if the international community is not prepared to provide finance and expertise to the most needy countries. Already, a number of countries which are trying to follow the Brazilian path (e.g. Bolivia and Paraguay), are finding it hard to overcome the financial and technical barriers. There is of course the danger that given the imbalance in research activities between the North and South, will lead to a situation where capital-intensive, high technology biomass options are the only ones which are readily available on the world market.[30] This is why Brazilian achievements could be very important to the South, if one considers that this technology would be more suitable to Third World markets.

Biomass energy is not the panacea to the world energy problem, nor will it be necessarily cheap or easily implemented without considerable commitment from governments. But biomass offers many great opportunities for indigeneous economic, social and technical developments, particularly in many developing nations.

1.4 Brazil's Drive to Industrialization

Brazil, as well as other developing countries that attempted to industrialize in the mid 20th century, has had to content with colonial social structures, extremely fast rates of population growth, the massive presence of foreign capital and the transfer of capital intensive industrial techniques from the industrial world. Brazil has been historically a primary production country highly dependent upon foreign demand while in recent decades economic growth was largely dependent upon an inflow of foreign capital.

The historical evolution of the Brazilian economy can be divided into three major periods which are briefly summarized below.

(I) <u>16th century till the Great Depression.</u> This is a period of primary products exporting era, based on the production of agricultural cash crops and mining. When Brazil was discovered by the Portuguese it was a vast territory sparcely populated with loosely structured Indian Communities.

The first staple product of value was dyewood, in demand in Europe for the textile industry. Then came the sugar, which the Dutch (1604-1654) built up into a flourishing industry and that became the principal engine of growth of the 17th century. Economic growth was dependent on exports since the domestic market was limited both by high transport cost and by the presence of a large labour force made-up of slaves whose subsistence needs were provided by their masters.

From 17th century onwards, Brazil experienced a series of booms, such as the discovery of gold (much of which contributed more to the rise of the City of London than it did to the development of Brazil), the French Revolution and the wars that followed that not only activated its economy but led to the break with Portugal in 1822 and the establishment of a predominant British economic position. From the mid 1830s coffee was to have a decisive role in shaping Brazil's subsequent economic development. Contrary to sugarcane planters, coffee growers were more commercially minded and entrepreneurial in their attitudes. They were also more in favour of development and to a certain extent were anxious to see Brazil emulate the European world. But so long as coffee was profitable there was not any strong reason why they should be interested in industrialization, and hence most manufactured goods continued to be imported.

The abolition of slavery in 1888 was a further necessary condition of the modernization process. Slave labour was immobile, remained in stagnant areas, while employers elsewhere were crying out for labour. Until the 1st World War, industrial development was on a small scale, but was growing. There had been sufficient growth in population and incomes to expand the home market for some goods with aid from tariffs. There was the beginning of the emergence of an entrepreneurial class investing in workshops, factories, and mills, particularly in Sao Paulo.[31] But the major characteristic of this period is economic stagnation.

II From 1930-1964, is based on "easy" import-substitution industrialization. A major feature was rapid industrial growth particularly in the consumer durable growth sector and heavy reliance on foreign direct investment. Industrial production grew at 9.6% per year during the period, one third of this growth was due to the activities of the MNCs.[32]

A major impact of the Depression was in the primary sector - the motor of the economy. There was a catastrophic fall in coffee prices and a fall in internal purchasing power and contraction of demand for manufactured goods. The lack of foreign exchange and the fact that home-produced articles became more competitive because currency devaluation, assisted a transfer of consumer demand from imported to home-manufactured commodities. A more conscious economic strategy was adopted after World War II. For example during the Vargas Administration, forced by Brazil's limited supply of foreign currency led to the passage of laws prohibiting the import of technology and equipment. As a result many MNCs moved in to Brazil, particularly the automobile industry.

After the 2nd World War British domination was replaced by U.S.A. whose main interest was to include the establishment of branch plants in Brazil, which have a direct impact on the industrialization process.

Without any clearly formulated ideology of economic growth or deductions analysis of Brazil economic position, the government embarked in a policy of industrialization of a more positive character based on ECLA (Economic Commission of Latin America) philosophy, that strong industrialization was the way out to Brazil's problems. From 1947 the government adopted a policy of selective import controls, aimed at curtailing the influx of consumer goods while still permitting the import of capital goods or raw materials required by domestic industry along the import-substitution path.

When the new industrialization policy began to take shape in the early 1950s, Brazil was still an underdeveloped country, despite the rapid development with the huge majority of the population lacking any purchasing power. The demand for industrial products came from the high income groups, very much influenced by, and desiring to emulate, the consumption standards and tastes of the high-income countries. Many of these wants, however, could only be met by imports.

The ISI strategy tended to encourage mainly the production of consumer goods for high income groups, not for the mass of the population. This type of demand could be met partly by local firms expanding and diversifying their production. As they did so, they found it necessary to import more advanced technology. Hence instead of importing consumer goods, Brazil was importing the machinery to make them. Furthermore, at some point the actual or potential market in Brazil for particular commodities became large enough to attract foreign firms to set up assembly or production facilities behind the tarrif wall.[33] The industrialization since the early 1950s has taken place in a series of forward surges followed by slowness due partly to the world market fluctuations and the self-generating cycle of reproduction and over-production.

President Kubitschek launched his administration, in January 1956, ambitiously aiming at "fifty years of development in five". Economic growth average 7%, reaching 10% at the end of his term in office. In some cases output increased dramatically, i.e. machinery by 125%, electrical equipment by 300% and transport equiapment by 600%.[34] But this growth was due to industrial imports at highly favourable rates. The most spectacular industrial contribution to this era was the founding of the automobile industry, around which new infrastructure was created. The problem with this strategy was that it aimed to replicate industries already flourishing elsewhere, but with the aggravating fact that all basic plant and technology would have to be imported. Thus the ISI strategy instead of reducing dependence on imports, has actually increased it, with a large number of MNCs, who moved in controlling the most modern manufacturing sector.

(III) Period 1964 Onward. The major characteristic is industrialization and export led growth which led to vigorous economic development and deepening poverty.

The new surge of industrial development was built in the infrastructure of previous years. The authoritarian regime isolated industrialization from pressure politics, with the State becoming the greatest producer of economic wealth, followed by the MNCs.

The new regime brought about a revision of economic policy away from national populism. Towards an approach which placed more emphasis on market forces, and further encouraged the inflow of foreign capital which together with the world favourable condition, were responsible for the rapid economic growth of 1968-1974. The major problem with the new ISI strategy was that continued industrialization became increasingly dependent on foreign capital and technology. Instead of breaking the "ties of dependency", continued growth became increasingly linked to investment by foreign capital and overseas demand. Although the nationally-owned industry has taken what advantage it could of the possibilities offered by the ISI strategy, continued industrialization required the resources of foreign firms owning the necessary capital and technology needed to establish more advanced industry. The ISI strategy has indeed prepared the way for expansion and capital accumulation, but instead of being the basis for national independence, as its advocates had hoped, it became the vehicle for the penetration of foreign capital on an unprecedented scale.[35]

Foreign investment has become concentrated in a small number of advanced industries - e.g. automobile, office equipment, pharmaceutical, plastic, electronics etc. The automobile industry is particularly important for its size and "multiplier effect" on Brazilian industrialization, spinning off thousands of factories and employing hundreds of thousands of people directly and indirectly.[36] Another characteristic of this period was the emphasis on exports, due to the failure of the industrialization processes to create a mass home demand for modern industrial products. This is due to the lack of purchasing power of the majority of the population. The output of modern consumer goods goes principally to the top 20% of the income receivers. In more recent years, the export drive policy has also been dictated by the need to earn foreign exchange to pay the foreign debt.

These distinct economic phases are associated with specific political and ideological systems. The economic structure of the primary exporting phase served to promote long-run stagnation, a highly differentiated social structure and an extremely skewed distribution of income within Brazil. Many of these structures established during the first phase still survive in a modified form until the present day and have conditioned the terms and format of modern industrialization.

What direction will industrialization take in Brazil, once the long economic recession is over? It should not be forgotten that the country is still only half way along the road to industrialization, despite the impressive advances; that its capital goods industry is still in a formative stage and hence its future difficult to foresee. How would Brazil be affected by the new technological revolution, considering that many of the country's industries are a duplication of those of the industrial countries?

Two major political steps seem to be necessary. Firstly to introduce social reforms so as to expand the purchasing power of the majority of the population, to create a large domestic market demand; secondly a deliberate policy to ensure rapid technological advances in those industrial sectors where Brazil can compete internationally - e.g. alcohol technology, light aircraft, and agricultural products. Brazil's advantages are real enough: ranging from enormous stretches of unoccupied land, abundant energy resources, technological creativity, large potential domestic market, among others.

1.5 Science and Technology in Brazil (S&T)

The development of scientific and technological capabilities in the Developing Countries have, for many reasons, been a difficult task and has assumed many different facets. Brazil, unlike most developing countries, already makes a considerable endeavour in this field. Strong scientific and technological capability is a prerequisite to sustained economic and industrial development.

The scientific activities in Brazil have been, however, weak, erratic and quite recent. The Brazilian scientific structure could be regarded as rigid and mostly state supported, with little funding coming from the private sector. Having been a colony, the country lacks scientific tradition.

During the Portuguese domination, not one printing press or university was set up. From 1500 to 1800 Brazil was deaf, dumb and blind, a scientifically negligible area of the world. In the late 1800s higher education consisted of two Medical Schools, two Law Schools and a School of Engineering and Mining with perhaps no more than 2500 students. Higher education in the first half of the 20th century was restricted to a very small group of citizens, with only three universities in the whole country. After the Second World War, there was an expansion of university education in both the state and private education system. But it was not until the 1960s when the education system was transformed under the Law No.4024.[37]

At the same time the industrialization process forced a number of MNCs - e.g. General Motors, General Electric, Westinghouse, to set up corporate institutes to educate technicians and professional engineers for their increasing sophisticated modernization demand. This industrialization process brought also to the attention of the politicians the importance of S&T.

Concern with S&T began, however, in 1947 with the creation of FAPESP (Fundaçâo de Amparo a Pesquisa de Estado de Sao Paulo); the CNPq (the National Research Council) and the CAPES (Companhia de Aperfeiçoamento de Pessoal de Ensino Superior) - see abbreviations, both set up in 1951.[38] Nonetheless little was achieved, since such policy was an attempt to copy the system operating in the industrial countries, which could not be transferred to Brazilian reality. A more realistic and serious attempt was made in the 1970s, with the creation of the PBDCTs (Basic Plans for the Development of S&T).

The first such plan (IPBDCT) in force from 1973-74, had the merit of focusing the attention on the importance of S&T to governmental circles and society in general. The IIPBDC from 1975-1979, attempted to increase public expenditure on S&T, reinforce the technological capability of the Brazilian enterprize. At the same time, the SNDCT (the National Scientific and Technological System) was restructured to meet the changes.[39] The IIIPBDCT, from 1980-1985 period, goes further than previous plans, and aims specifically to the need to attain greater scientific capability and technological autonomy. It acknowledges the necessity to change the situation of dependence of Brazil in relation to industrial countries; the need to develop scientific and technological knowledge as a precondition to overcome economic difficulties.

The document gives priority to the creation of conditions and mechanisms for the generation of technology at local levels; pledges greater financial support and participation of the Scientific Community in the formulation of policy.[40] The general situation, however is summarised well by Schartzman:

> "the recent expansion of S&T, and higher education stems from a combination of several interrelated trends: an increasing demand for professional universities degrees, an increasingly demanding scientific community, and more involvement by agencies of economic planning in the field of S&T. With all of these trends are associated different institutions, persons and outlook. They are not necessarily compatible; they often clash with each other. Scientific development in Brazil is hindered by lack of consistent economic policy regarding the use of technological resources, by the limited power and stability of the scientific community and its weakness in the face of government authorities in education, science and technology.
>
> The establishment of plans for scientific, technological and educational development has generated very complex systems of evaluation, which creates large amounts of paperwork and much delay. Scientists are often involved in these activities as advisers, members of review boards and consultants; final decisions, however, are taken by civil servants and politicians who seldom justify their decisions in public."[41]

A significant change is represented by the fact that the World Bank has chosen Brazil for its first test of a new aid package, aimed specifically at modernizing S&T in Developing Countries. According to this package Brazil will receive $548m to assist with the PADCT (the Programme for Support in the

Development of Science and Technology) for the next five years, as illustrated in Table 1.1. Chemistry, Biotechnology and Basic Industrial Technology are among the greatest beneficiary sectors.

Insofar as the expansion of higher education is concerned, this has been very rapid indeed. Student enrollment grew from 124000 in 1963 to over 1.5 million in the early 1980s. There exist more than 900 educational establishments of which 61 are universities. A further indication is the rapid increase of the number of people holding PhD degrees, as illustrated in Table 1.2. This increased from 132 in 1974 to 875 (estimated) for 1985. The total for the same period is 5757, with biology in first place with 1442 and basic sciences with 1010. The table excludes any other type of degrees (e.g. MSc or PhD candidates).

At the end of 1983, there were 1699 institutions involved in some kind of research with 11982 research projects. Of these institutions 1118 were private and state companies and the rest, 581, research centres, educational and government institutions. The most important states in research activities are SP, RJ, RS, and MG.[42]

Table 1.3 shows Brazilian expenditure on S&T and the percentual equivalent of the GDP from 1973 to 1984. This share increased from 0.20% of the GDP in 1973 to 0.70% in 1984. This percentage has increased constantly, despite the fact that total expenditure on S&T has declined from $1.86 billion in 1982 to an estimated $1.36 billion in 1984, due to the economic recession. If present trends continue, Brazil would be expending on S&T as much as many industrial countries, in percentage terms. However, I should point out the difficulties in knowing how much money is actually spent in R&D and how much is lost in bureaucratic costs, which in my understanding are high. Hence these figures should be seen with caution. This steady increase on S&T expenditure has been the consequence of an increasing interest on S&T prompted by a greater awareness among the politicians by the importance of S&T in the industrialization process.

Table 1.1 World Bank Financed Programme for the Support in the Development of Science and Technology in Brazil.

Basic Programme	($ Million)
Science education	43.60
Biotechnology	89.88
Chemistry	114.20
Geoscience and mineralogy	89.90
Instrumentation	40.00
Additional Programme (begins in 1986)	
Basic industrial technology	93.52
Information and documentation	15.96
Investment planning	16.00
Special reagents	15.00
Equipment maintenance	27.95
Total	546.01

Source:
Joyce C. Research recovers from the dark age, New Scientist 107 (1465) 18 July 1985, p. 37.

Table 1.2 Number of Ph.D Degree Graduating According to Field of Study, 1974-1985.

Year	Pure Science	Biology	Engineering	Health	Agricul. Science	Human*	Total
1974	51	61	0	14	6	0	132
1975	47	45	10	15	9	12	138
1976	69	67	5	13	13	21	188
1977	73	93	28	49	26	47	316
1978	88	121	18	63	42	44	376
1979	89	166	19	92	40	77	483
1980	107	167	25	66	42	132	539
1981	123	118	50	56	40	121	508
1982	84	99	58	81	55	295	672
1983E	119	158	56	95	60	242	730
1984E	126	168	63	104	66	275	802
1985E	134	179	69	113	72	308	875
Total	1010	1442	407	761	471	1574	5759

Notes:

* Including Social Sciences

E Estimated

Source:

R.B.T. 15 (6) November/December 1984, p. 64, table 3B.

Table 1.3 Gross Domestic Product (GDP) and Expenditure on Science and Technology (S&T), period 1968-1985.

($ Billion)

Year	GDP(a)	Index(b)	S&T Expenditure(c)	Exchange rate (Cr$=US$1)
1968	45.8	83.6	-	3.57
1969	44.5	91.6	-	4.05
1970	43.0	100.0	-	5.56
1971	49.1	112.0	-	5.25
1972	58.1	124.5	-	5.93
1973	78.9	141.4	0.15	6.12
1974	104.3	155.1	0.22	6.79
1975	124.3	163.5	0.43	8.12
1976	152.3	179.4	0.60	10.67
1977	176.0	189.7	0.90	14.13
1978	208.4	199.2	1.04	18.06
1979	234.9	211.9	1.26	26.87
1980	249.8	227.2	1.35*	52.69
1981	275.4	223.6	1.64*	93.06
1982	283.3	225.7	1.86	179.39
1983	210.1	218.6	1.48*	576.16
1984	195.6*	220.0*	1.36*	2000.00
1985	-	227.4*	-	

Notes:

(a) It is usual to use the GDP rather than the GNP for calculating S&T expenditure.
(b) Index 1970= 100
(c) R&D, innovation and other scientific and technological activities.Refers mostly to government institutions.
* Estimated.

Source:

R B T 15 (5) September/October 1984, p.61, table 1B.

Despite this increase on S&T expenditure, however, the expansion of industrial production appears to be very much linked to imports of technology, as can be observed in fig 1.1. This despite government measures to reduce such imports.[43] The rapid economic growth of the 1960s and the initiation of heavy public investment led to a sharp increase in technology imports. The sharp decline of technology imports in the late 1970s and early 1980s, was first due to measures to curb imports and secondly to the economic recessions. At the same time one can notice a steady increase of Brazil's technological exports.

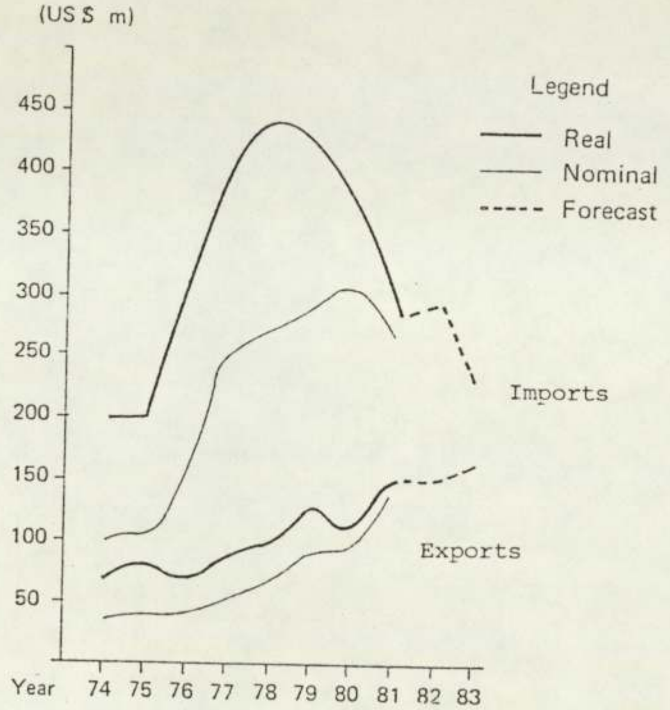
The economic crisis has, of course, forced the abandonment of many research projects because of lack of resources.[44] Another problem which is worth noting, is the little concern of the private sector for R&D. Historically the private sector in Brazil has been keen to import technology rather than invest in R&D. With the economic recession - where companies are struggling to survive, investment on R&D is at its lowest level,[45] leaving the public sector almost solely responsible for R&D.

The university system is considered on the other hand, where most research is carried out, by many industrialists, as "centres of impractical knowledge". For example, in 1978 of the 2291 patents owned by Brazilians, 55.6% came from companies; 44.3% were registered by individuals and only 0.1 (two patents!) came from the universities and other technological centres.[46] The new Administration appears to be more concerned with S&T and has set up for the first time, a Ministry of Science and Technology, but headed by a politician rather than a Scientist.[47]

1.5.1 The PRONAB

Biotechnology has an immense potential for development in Brazil, given its biomass-related energy programme and agricultural potential. The task of meeting increasing food demand and energy needs can be greatly enhanced by modern biotechnolgical techniques. It would be of great importance that the

Fig.1.1 Import/export technology (nominal and real value), 1974 - 1983.



Source: Revista Basileira de Tecnologia, 14(3) May/June, 1983, p. 65.

country fully master biotechnology in these specific areas. Since Brazil has a long tradition in biomass, this area offers one of the most realistic technological opportunities for making useful technological advances and to provide suitable infrastructure for biotechnology to build on.

Despite the fact Brazil was not able to formulate the PRONAB until quite recently, it is one of few Developing Countries which has a biotechnology policy.[48] However, the PRONAB, as first published, appeared to be too ambitious and unrealistic for the Brazilian conditions,[49], and was consequently revised.[50] Biotechnology would be, according to Table 1.1, one of the greatest beneficiaries of R&D, chiefly in health, agriculture and energy (see table 1.4). The most important items are new projects with $26.3m; infrastructure $24.6m; and human resources with $14.2m. These are preliminary figures only, and hence they should be regarded as rough estimates.

Brazil has already significant research programme in some areas of biotechnology. For example in plant biology, there are at least 16 centres carrying out research employing biotechnological techniques, ranging from conventional genetic techniques to cell tissue culture, in a number of important agricultural commodities.[51]

Currently however, there are important limiting-factors to biotechnological developments in Brazil. These can be summarized as follows: (i) lack of a strong base in basic sciences, particularly physiology and biochemistry of microorganisms relevant to biotechnological industrial process; (ii) weak base in physiology, biochemistry and plant genetics, which inhibits progress in the key biotechnological areas of agriculture and energy; (iii) lack of human resources, well trained, in the interdisciplinary area of biotechnology for scientific and applied research. In 1984 there were 610 researchers in this field, all types including technicians, 194 each in health and agriculture and 222 in energy; (iv) lack of adequate mechanisms between universities, research isntitutions; (v) inadequate mechanisms for marketing biotechnology products.[52]

Table 1.4 Breakdown of the Proposed Expenditure in Biotechnology ($ 10^3)

Year	1	2	3	4	5	Total	%
Human resources	2 305	1 885	4 257	3 423	2 347	14 217	16
Infrastructure	2 400	3 600	8 400	8 400	4 800	24 600	31
New projects	1 965	1 965	6 673	7 213	8 523	26 339	29
Scientific Exchange	729	804	1 457	1 457	1 457	5 904	7
Planning, etc	436	458	782	784	739	3 199	3
Pilot Plant	1 700	1 050	950	850	200	4 750	5
Services	1 696	1 258	1 134	1 059	1 010	6 157	7
Tech. Assistence	100	100	420	580	520	1 720	2
Total	11 331	11 120	24 073	23 766	19 596	89 886	100

Source:
CNPq.

To overcome these deficiencies is a major challenge. Judging by the historical experience, the state would have to play a key role in providing the necessary financial resources and leadership in R&D activities, since the private sector seems to be reluctant to invest. However the World Bank loan is an important step forward.

Of the three priorities research areas of PRONAB, two concern directly the ProAlcool: agriculture and energy. The objectives can be summarized as follows. (i) Agriculture: the PRONAB believes that advances could be made by crop improvements through the use of tissue culture and genetic engineering. Specific project objectives are: to develop N_2 fixation microorganisms adopted to different Brazilian conditions; to increase photosynthetic efficiency, with emphasis on forage crops; to develop improved systems of biological pest control; to develop new yeasts and fertilizers, etc. (ii) Energy. The priority research objectives include: the production of alternative renewable energy sources; the development of new technologies for production of ethanol from sugarcane and starches containing materials and cellulose and new process technology; production of biogas; production of new microorganisms more tolerant to ethanol; research on enzymatic hydrolysis.[53] The PRONAB represents an opportunity and challenge to those concerned with biotechnology in Brazil. It would demand governmental commitment if sufficient resources are to be allocated, contrary to the industrial countries where most financial support comes from the private sector. In the area of health and many aspects of agriculture the MNCs are very likely to play an increasing role in worldwide biotechnological developments because they have the resources, know-how and marketing structure. In many aspects of ethanol production, Brazilian firms are in a privileged position which should be capitalized on.

1.6 Energy Trends and Policy

A major criticism of Brazil's energy policy has been, precisely, that it did not have such policy until relatively recently. The first major step was the creation of the CNE (National Energy Council) and the establishment of the MEB (Brazilian Energy Model) containing a series of five years plans with specific goals to be attained.[54] Energy planning has been based on supply rather than demand, and a reflection of the industrial countries model. With a centralized decision-making structure, many vital decisions were taken without a comprehensive and feasibility study, and hampered by lack of consultation and public discussions.[55]

To make it brief, Brazil entered the decade 1970s with an energy structure which can be summarized as follows. (a) a very significant participation of biomass, particularly wood in the rural sector, but declining due to the penetration of LPG which was heavily subsidized; (b) an absolute dominance of hydroelectricity for electricity generation and in marked ascendency; (c) a sharp increase of petroleum consumption, particularly in transportation, supported by the rapidly expanding automobile industry. Table 1.5 shows the energy trends in Brazil from 1973-1983. The main features are a relative decline of petroleum of the primary energy consumption from 42.3% in 1973 to 33.6% in 1983; an increase of hydroelectricity from 19% to 28.8%; and renewables from 54.1% to 60.8%, respectively.[56]

Among the main energy decisions in the 1970s was the intensification of domestic oil drilling; the creation of the PNA and "NucleBras" (Brazilian Nuclear Energy Company). In the late 1970s a new macroeconomic policy emerged, as a consequence of the second oil crisis, with the creation of the MEB. The main objectives were the gradual reduction of imported oil and energy conservation. Petrol consumption was to be maintained at one million barrels per day (1.m.b.d.) for the period 1979-85. Any additional demand was to be met by energy savings and increase use of alternative renewable energy sources.

Table 1.5 Primary Energy Consumption - 1973-1983 (10^3¢p.e.)

YEAR	PETROLEUM	NATURAL GAS	STEAM COAL	COAL FOR METALLURGY	URANIUM H2 09	HYDRO/ ELECTRICITY	WOOD	SUGARCANE	OTHERS (1)	SUB-TOTAL RENEWABLE	TOTAL
1973	37,866	259	613	1,818	-	16,788	23,899	7,051	121	47,859	88,415
	42.8	0.3	0.7	2.1	-	19.0	27.0	8.0	0.1	54.1	100.0
1974	39,796	520	629	1,784	-	19,047	25,343	7,043	127	51,560	94,289
	42.2	0.5	0.7	1.9	-	20.2	26.9	7.5	0.1	54.7	100.0
1975	43,994	571	652	2,197	-	20,963	26,793	6,351	134	54,241	101,655
	43.2	0.6	0.6	2.2	-	20.6	26.4	6.3	0.1	53.4	100.0
1976	46,794	627	597	2,813	-	24,045	27,234	7,232	161	58,672	109,503
	42.7	0.6	0.5	2.6	-	22.0	24.9	6.6	0.1	53.6	100.0
1977	47,901	1,085	727	3,338	-	27,109	26,735	9,447	166	63,457	116,508
	41.1	0.9	0.6	2.9	-	23.3	23.0	8.1	0.1	54.5	100.0
1978	53,405	925	1,151	3,369	-	29,797	26,522	10,125	184	66,628	125,478
	42.6	0.7	0.9	2.7	-	23.7	21.1	8.1	0.2	53.1	100.0
1979	55,576	983	1,099	3,859	-	33,382	27,266	11,265	236	72,149	133,666
	41.6	0.7	0.8	2.9	-	25.0	20.4	8.4	0.2	54.0	100.0
1980	54,318	1,133	1,206	4,044	-	37,641	28,509	12,378	335	78,863	139,564
	38.9	0.8	0.9	2.9	-	27.0	20.41	8.9	0.2	56.5	100.0
1981	52,592	1,069	1,794	3,617	-	37,922	27,915	13,523	470	79,830	138,902
	37.9	0.8	1.3	2.6	-	27.3	20.1	9.7	0.3	57.4	100.0
1982	52,032	1,463	2,196	3,768	1,154	40,928	28,541	15,205	508	85,182	145,795
	35.7	1.0	1.5	2.6	0.8	28.1	19.6	10.4	0.3	58.4	100.0
1983	51,103	2,008	2,163	4,476	-	43,927	29,341	18,843	408	92,519	152,269
	33.6	1.3	1.4	2.9	-	28.8	19.3	12.4	0.3	60.8	100.00

Source: (MME, 1984)

(1) Agricultural waste, and heating generating industries

Oil imports were reduced by 50%, thanks to these measures. More significant, however, was the deliberate policy to increase domestic oil production in the shortest possible of time. This resulted in a rapid increase in oil production from 174 x 10^3 barrels per day (b/d) in 1973 to 460 x 10^3 in 1984 (see Table 1.6) and estimated 5 x 10^5 in 1985. This represents an annual growth of 22% in the past five years. As we shall see later the policy is to produce l.m.b.p.d. by 1993.

Brazil's success in finding new oil fields has raised much optimism and hope that the country may become self-sufficient in oil production. In this case, what would happen to the ProAlcool? First, according to an interview given by the former President of Brazil, Geisel, it is very unlikely, but even if such self-sufficiency could be achieved, it would not last long because of the increasing energy demand in Brazil. He therefore strongly defended a diversified energy policy.[56] In addition, drilling and exploration costs are very high in Brazil (see 8.2.1). Secondly, according to the ProAlcool observers, if the country one day discover large reserves of oil, it would make more economic sense to export it, rather than to dismantle the ProAlcool, considering the enormous social ramifications.

1.6.1 The Energy Self-Sufficiency Scenario

No one could deny Brazil's achievements in the energy sector in recent years. External energy dependency has been reduced from 37.5% in 1979 to 22.2% in 1983; and oil imports from c.10^6 to 6.4 x 10^5 respectively.[57] This remarkable success has prompted the MME to issue a document in which it states a policy of self-sufficiency scenario to be achieved by 1993.[58] This would have been unthinkable just a decade ago. The document proposes the following line of action. (i) the total petroleum consumption to be kept at l.m.b.p.d.; (ii) any additional energy demand over this limit, to be met by renewable energy sources.

The share of non-renewables would decline from 41% in 1983, to 35.7% in 1993; whilst the share of renewable sources would increase from 59% to 64.3%

Table 1.6 Brazil: Consumption and Output of Crude Oil, 1973-1984
(10^3 Barrel/day)

Year	Total consumption	Increase %	Domestic production	Increase %
1973	787	21.6	174	1.8
1974	854	8.5	182	4.6
1975	904	5.9	177	-2.7
1976	985	9.0	172	-2.8
1977	1 003	1.8	166	-4.5
1978	1 095	9.2	166	-
1979	1 165	6.4	171	3.0
1980	1 122	-3.7	188	9.9
1981	1 062	-5.3	220	17.0
1982	1 056	-0.6	268	21.8
1983	954	-9.1	340	26.9
1984	960	-	460	35.3

Source:
The Financial Times Survey, November 1984, p. iv

respectively (see table 1.7), this means an increase from 1.4 x 10^6 b.d.p.e. to 2.8 x 10^6 on the same period.

Hydroelectricity is of course the most important renewable energy source, which has increased its share dramatically from 19% of total primary energy consumption in 1973 to 28.8% in 1983 (or 6062 MW) to a proposed 36.4% in 1993 (or 12183 MW) excluding thermal generation capacity. This potential is, unfortunately, very unequally distributed, and utilized, and far away from the main consumption centres.[59] It is also becoming more expensive as the main waterfalls are progressively used up.

In the past decade electricity demand increased faster than the GDP due to the introduction of energy intensive industries, urban population growth, substitution of other fuels by electricity, but more significantly, due to planning errors based on grossly over-optimistic economic growth estimates. Therefore there exists an overcapacity and hence it is possible that demand for hydroelectricity in the future will grow at a much lower pace.[60]

The MME's scenario foresees a gradual reduction of imported oil until its total elimination by the end of 1992, replaced by the domestic oil production, as illustrated in Figure 1.2. This represents a dramatic change from the previous scenario (number 3 in figure) which forecasted oil imports of 9 x 10^5 b.d. in 1993. This scenario's main assumptions are based on energy trends from 1973 to 1983, and assumes that the energy intensive industries (e.g. steel, cement, chemicals etc) would be using more energy efficient technology than in the past. The economic growth estimates for this scenario is 3% for 1985; 4.1% for 1986; 5% in 1987/88, and 5.6% for 1989-93.[61]

To achieve energy self-sufficiency, the MME plan is to invest $115.5 billion in the energy sector up to 1993, of which $8.5 billion would be on production of alcohol from sugarcane, plus reforestation for energy purposes. On petroleum and electricity would be invested $105.3 billion or 91% of the total. The overall investment in the energy sector which in the past ranged from 3% to

Table 1.7 Total and Estimated Energy Consumption, 1973-1993 Period.

(10^3 barrel/day petrol equivalent)

	1973	(%)	1983	(%)	1993.	(%)
NON-RENEWABLES	728	48.0	1013	41.0	1584	35.7
-Natural gas	2	0.1	23	0.9	160	3.6
-Coal	1	0.1	29	1.2	104	2.3
Petroleum derivatives(1)	665	43.8	854	34.5	993	22.4
-Diesel oil	157	10.4	296	12.0	356	8.0
-Diesel fuel	180	11.9	174	7.0	90	2.0
-Gasoline	207	13.6	135	5.5	169	3.8
-Others	86	5.7	169	7.3	176	7.1
ELECTRICITYY (2) (thermal)	32	2.1	35	1.4	216	4.9
Other non-renewbles	28	1.8	72	3.9	111	2.5
RENEWABLES	790	52.0	1461	59.0	2853	64.3
-Wood	389	25.6	405	16.4	606	13.7
-Hydroelectricity	282	18.6	773	31.2	1615	36.4
-Charcoal	39	2.6	79	3.2	116	2.6
-Sugarcane bagasse	72	4.7	126	5.1	241	5.4
-Ethanol	8	0.5	77	3.1	256	5.8
-Other renewables	-	-	1	-	19	0.4
Total (3)	1518	100	2474	100	4437	100

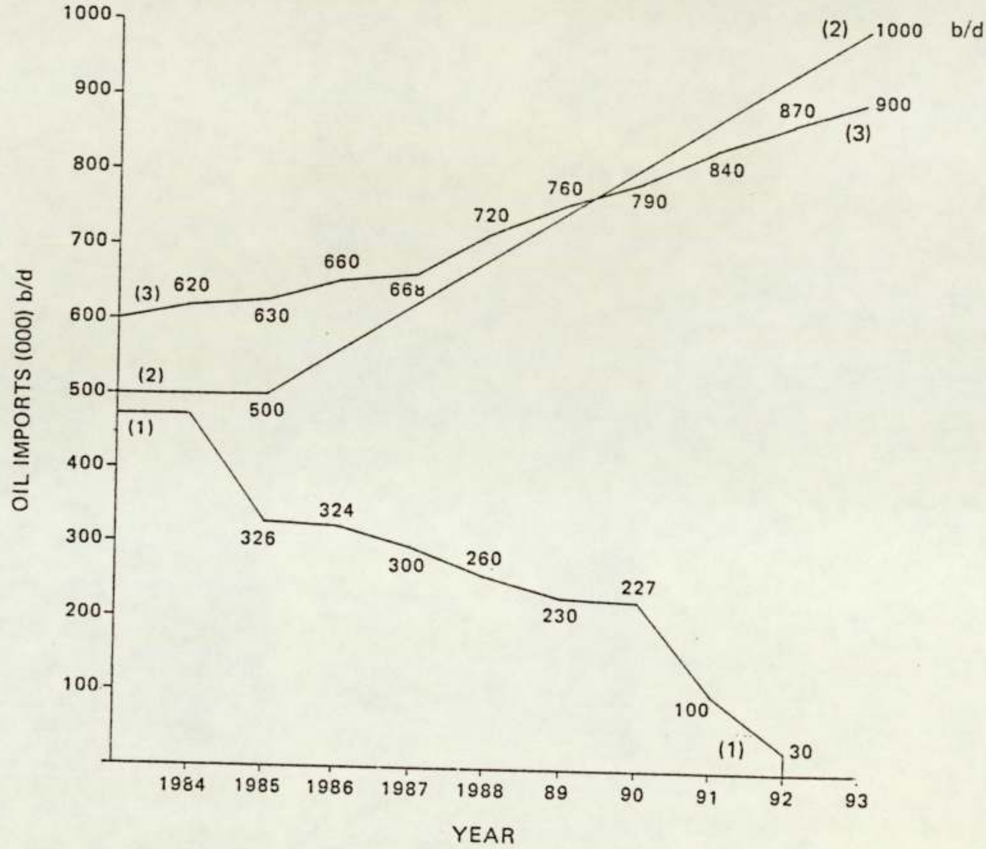
Notes:

(1) Including natural gas derivatives
(2) Coal, diesel oil
(3) Excluding cooking gas and sugarcane for non-energy uses

Source:

Based on Auto-Suficiencia Energetica data (MME) July 1984.

Fig. 1.2 OIL IMPORT ACCORDING TO THE SELF–SUFFICIENT SCENARIO



SOURCE: BASED ON MME DATA

(1) Oil imports according to the energy self-sufficient scenario of the MME 1984.

(2) Domestic oil production, as scenario (1).

(3) Previous plan. (Oil imports)

3.9% of the GDP, is proposed to be increased to 4% from 1985-1993. The proposed investment on oil exploration ($56.7 billion) is the estimated equivalent savings in oil imports.[62]

Although there must remain many doubts whether these objectives can be fulfilled, or even if it is partially successful only, it represents nonetheless a remarkable change in Brazil's energy outlook. This would not only give the country far greater energy independence, but would enable the country to reduce considerably its foreign debt burden.

CHAPTER 2

THE PRODUCTIVE STRUCTURE AND R&D EFFORTS OF THE PROALCOOL

Introduction

In this chapter I address five main aspects related to the ProAlcool: (i) the agricultural sector, a key issue in the success of failure of the programme in the long term; (ii) the underlying reasons which led to the set up of the P.N.A., and a range of early handicaps; (iii) the production structure of the alcohol sector, so deeply rooted in the socioeconomic nature of Brazilian society; (iv) scenarios of possible alcohol production; (v) major R&D efforts to develop alcohol production/utilization technology and some hindering factors.

2.1 Agriculture

The implementation of a large-scale programme of the nature of the ProAlcool is bound to have far reaching implications with regard to agriculture. A major weakness, up to now, has been the tendendcy to judge the P.N.A. without paying the necessary attention to such implications. Agriculture is the key to the success or failure of the programme. Modernization,[1] increased productivity and structural changes are serious challenges which must be overcome if the P.N.A. is to be consolidated in the long term.

However, a major concern from a policy point of view, would be whether agriculture can withstand the challenge of (i) providing increasing domestic food demand; (ii) meet energy requirements; (iii) continue to be a major source of foreign exchange earnings, by providing an increasing production of commodity exports; (iv) whether there would be sufficient financial resources to meet the increasing demand for investment in the agricultural sector.

Until the 1950s agriculture played a secondary role in the Brazilian industrialization process. Agricultural policy consisted essentially of giving as much support as possible to the politically powerful groups (e.g. coffee plantation owners), and leaving the rest of the farmers to the mercy of the weather and bank managers. The result was that the non-traded domestic food crops sector was left behind without government support, under-capitalised; technically backward and with very low productivity.[2]

The modernization drive of the Brazilian agriculture began in the late 1960s. Since then, agriculture has undergone a rapid change, particularly in the South-East region. Since the 1960s, governments have regarded agriculture as the sector with the greatest potential for economic growth; specifically for exports, because this is an area where Brazil can compete internationally. Large parts of Brazilian territory consist of scrub land or forest which can easily be transformed into farm land with relatively small investment in land clearing. The country has made great strides in improving agricultural foodstuffs production, due to the priority on agricultural investment, but also thanks to Brazil's exclusive and varied geography. Yet at the same time, it is worth recalling that food production for domestic consumption has declined steadily during the past decade (see Table 8.5).

Agricultural modernisation took place against a background of political authorization, which allowed the large farmers to make most of the economic gains. At the same time the rural workers were unable to benefit and express their views. The new policy instead of being aimed at finding a solution to the domestic market, was basically orientated to ensure the rapid expansion of commodity export crops, to pay for the industrialization process. To contain the possible impact of inflation caused by insufficient supply of foodstuffs, the government followed a policy of price and wages control.[3]

The modernization process was further accelerated in the 1970s through a "rural credit policy" which consisted in providing cheap subsidized credit to the farmers, as it is illustrated on Table 2.1, in comparison to the commercial bank rates.

Table 2.1 Interest rate changes of commercial banks and rural credit, 1978-1983 (%)

Interest rates/year Year	1978	1979	1980	1981	1982	1983
Commercial market	63.0	82.0	101.5	118.0	147.0	197.0
Rural Credit	15.0	33.0	45.0	59.6	72.8	117.2

Source: Instituto de Economia Agricola de Sao Paulo.

The domestic food situation was further complicated in the late 1970s and early 1980s due to the rapid deterioration of Brazil's foreign debt. In order to pay such debts and much needed imports, the government was forced to look to the agricultural sector to increase exports.[4] Therefore the tendency was to provide financial credit to those farmers producing export commodity crops. For example, 80% of all rural credit in 1981 went to ranch crops - i.e. soya bean, corn, coffee, sugar etc. The traditional staple crops, e.g. cassava, and black dry beans, received only 4% of the total credit in the same year.[5] The rural credit benefited mostly the large farmers because (i) they were already producing export-orientated crops or had the means to produce them; (ii) because, usually, they could guaranteed repayment of the loan. Thus, the large farmers community was able to capitalize on the "rural credit policy" more than any other rural sector.[6]

Agricultural modernization brought important socioeconomic changes in the rural milieu. It led to greater land concentration and changes in land ownership, proletarization of the labour force and massive imigration to the cities. Over 15 million people left the agricultural sector in the 1970s alone.[7]

Unlike 19th century Britain or the USA, rural surpluses could not be absorbed by the expanding Brazilian industrial sector. Whilst in the USA, e.g. there was a labour shortage and mechanization was labour-saving oriented, in Brazil, which followed the same path, the conditions were very different. Firstly, there was a very large rural sector and a rapid population growth; and secondly a smaller industrial sector, much less labour-intensive than the USA and Britain in 19th century, which was unable to absorb the labour surplus. The consequence has been the creation of a huge unemployed or semi-employed labour sector crowed in to the big cities.[8]

Land concentration has been also evident. In the 1960s the 50% of the lower income farmers received 22% of agricultural production and by 1980, it was down to 17.6%. In 1970 the 5% largest landowners - 250,000, received 67% of agricultural income and by 1980 it represented 70%.[9]

The active support of the Federal Government, for agricultural modernization, can be summarized on two main points. (i) the need to earn hard currency, first to pay for the industrialization, foreign debt and imports, (ii) the need to increase agricultural productivity, and guarantee the industrial sector with cheap raw materials and labour force.

This policy, however, did not include any major land reform.[10] There seem to have been three main reasons: (i) the political power-base of the regime, particularly from the mid 1960s, was largely dependent on the large landholdings class; and hence there was not a political interest in antogonizing this class; (ii) the ability of farmers to increase productivity rapidly. This was achieved by intensive use of modern inputs (e.g. machinery, fertilizers, pesticides etc, which they could acquire thanks to the "rural credit policy"). At the same time it weakened the position of those supporting land distribution as a pre-requisite to increasing productivity. The State, therefore, sided in favour of preserving the "status quo"; (iii) there existed large areas of un-utilized land which could be used for new cultivation.[11]

It is important to analyze the P.N.A. within this context since many of the problems for which the programme has been blamed, merely reflect agricultural policy and trends of Brazil's socioeconomic and political model.

Despite the significant success in the drive to modernization of the agricultural sector, important policy changes would be needed to accommodate the increasing demands on agriculture. For example there exist a dual reality: a modern agricultural sector responsible for much of agricultural output, co-existing alongside a traditional and low productive one.[12] Until now, a major drawback has been the lack of a long term strategy for the agricultural sector. The new Civil Administration appears to be preparing important policy changes with regard to the agricultural sector - e.g. to give greater priority to domestic food demand.

Low productivity remains a major challenge and its improvement should be the core of the agricultural policy, combined with opening up of new agricultural lands. Undoubtedly that important structural changes would be needed, despite the existence of abundant supply of land, as illustrated on Table 2.2. In 1980 only 40×10^6 ha.of the 306.6×10^6 ha. were cultivated for domestic and export crops, while the expected cultivated area for the year 2000 is 144.6×10^6 ha. including 15.6×10^6 ha. for energy crops. However, these facts do not consider land ownership patterns, which is heavily concentrated.[13]

2.2 The Modernization Programme of the IAA, 1971-1975 and the Origins of ProAlcool

In the early 1970s, the sugar cane producers, encouraged by the high price of sugar in the international market, embarked on a far reaching modernizing programme designed to improve the extremely low agricultural and industrial productivity of the sector. In was the beginning of a large-scale capital intensive modernization drive.

To modernize the industry and introduce new technology, the IAA established a financing system for expansion and modernization of plantations and mills. The financial resources needed to carry out this modernization project were to be provided by the IAA's Special Export Fund, whose revenue was generated from the differences between the established price paid to the sugar

Table 2.2 Brazilian Land Use: 1980-2000(10^6 ha.)

Suitability of land	Land suitable for temporary and permanent crops		Land suitable for forestry and pasture only		Urban areas, agricultural unsuitable land	Total
	306.6		325.1		211.1	844.9
	1980	2000	1980	2000		
Domestic and export crops	40.0	129.0	-	-		
Forest & pastures	-	-	89.4	307.0		
Energy crops (except forestry)	0.78	15.6	-	-		
Land availability	267.8	164.0	235.7	211.1		

Source: STI/MIC Assessment of Brazil's National Alcohol Program, Brasilia 1981, p. 28, table 4.3.

producers and the international market price received by the IAA. Higher world prices would provide more resources for the expansion of the industry and for the modernization programme. This Fund made available enormous resources for modernization, at lower interest rates than inflation. This created a strong incentive to the sugarcane producers to invest in the industry.

However, the volatile sugar market changed rapidly and by mid 1975 world sugar prices began to plummet. In early 1974, sugar prices reached US $1,400 per ton[14] and by mid 1976 prices fell to US $150 (see Fig 2.1) and have continued to fall ever since. The consequences for the sugar industry were obvious. Brazil withdrew from the spot market and thereafter serious problems of overcapacity of the industry began to emerge. There were two major options open to the industry: (a) to expand the domestic market - a difficult operation because the market was not large enough to absorb existing surpluses; (b) to produce alcohol. This is something which Brazil had done previously.

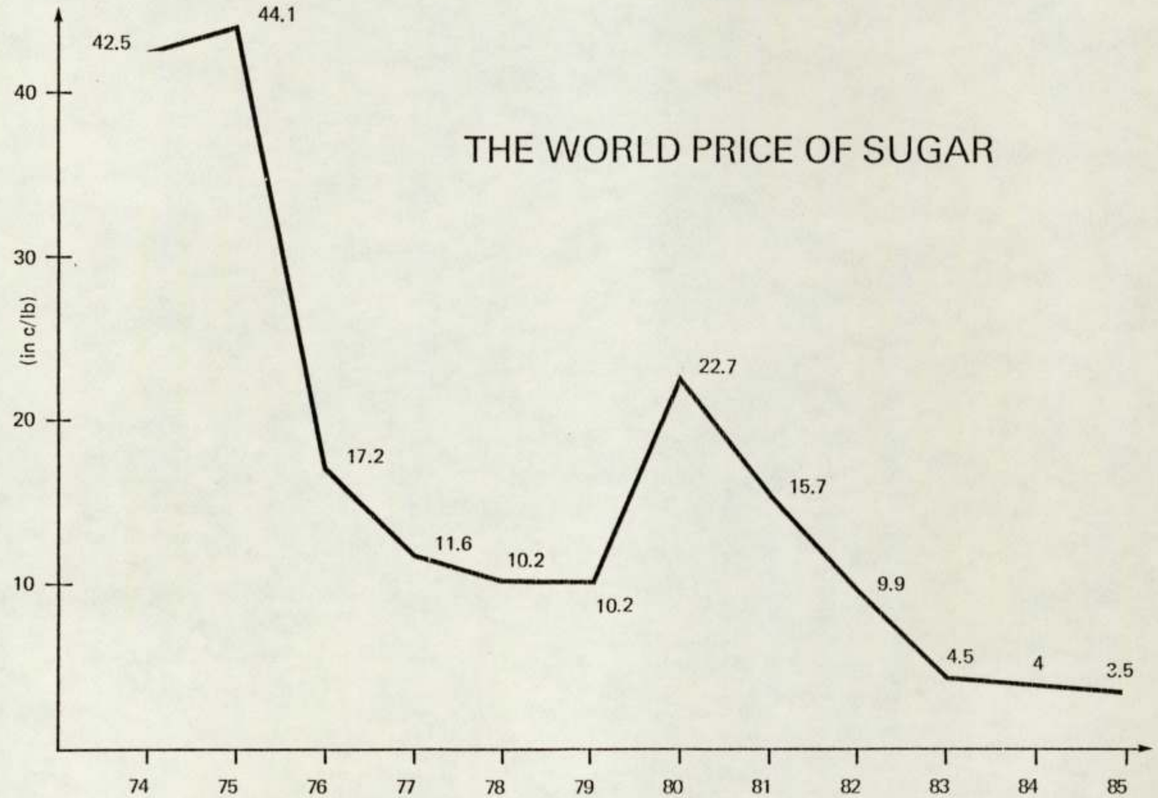
The government was also faced with the problem of maintaining rural employment and making use of the extensive capital investment recently committed to the sugar sector. The crisis situation coincided with government efforts to define an alternative energy programme. As Barselay puts it

> there would have been no November 1975 decree if Brazil had not already developed a tremendous capacity to produce sugar cane, and capital investment that would have been threatened by the collapse of world sugar prices unless the government decided to protect the industry.[15]

The creation of the P.N.A. has to be analyzed within the context of the sugar industry which played a major role in setting up the programme.

Despite its short history, the alcohol programme had to confront a number of problems, political rather than technical; it has been hindered by bureaucratic problems and policy inconsistency. To start with, those who opposed it maintain that the programme was launched without sufficient technical studies to test its viability, and without proper consultation. This is denied by Bautista Vidal[16] but he also recognized that the ProAlcool did not become public knowledge until

Figure 2.1



SOURCE: NAVARRO L, THE EXPORT POTENTIAL OF ETHANOL TO DEVELOPED COUNTRIES, (GEPLACEA), MEXICO, JUNE 1985.

President Geisel visited the CTA where tests were being carried out.

In the first few years of the programme, the decision-making process revealed a complex highly fragmented structure of decision. Multiple centres of decision without clearly defined tasks, and competition among bureaucratic agencies. The great number of bureaucratic agencies involved in the P.N.A. - with their contradictory statements and actions - was a major cause of the difficulties in the programme's implementation.[17]

The scope of the bureaucratic inefficiency can be realized by examining Table 2.3 which lists 20 organizations that have a role on policy. This fragmentation of power prevented the State from solving, in the early stages of the programme, three particularly important roadblocks to the establishment of the alcohol sector: (i) administrative control due to bureaucratic competition for the control of the P.N.A.; (ii) the State's difficulties to determine future production of alcohol; (iii) shortages of financial resources, which also stemmed from the fragmented public finance decision-makers, e.g. The Treasury, Bank of Brazil, Central Bank etc.

Today the number of agencies involved is about the same, yet complaints have disappeared and the decision-making structure is functioning smoothly. As Castro Santos puts it

> "The apparent "Tower of Babel" which is the complex, highly fragmented structure of decision-making for alcohol policy, works, and works quite well for large capital."[18]

2.2.1 First Phase of the ProAlcool, 1975-1979

Despite the short history of the P.N.A., four main phases can be distinguished. A major characteristic of the first phase was the non-definition of a centre of decision-making for production activities. Alcohol production was based on taking advantage of existing sugarcane cultivation infra-structure, particularly in the State of S.P. Alcohol was produced almost exclusively from sugarcane.

Table 2.3 The Bureaucratic Structure of the PNA.
(Organizations linked to the alcohol programme).

1- Ministry of Trade and Industry (MIC)
2-National Alcohol Commission (CNAL)
3-National Executive Alcohol Commission (CENAL)
4-Institute of Sugar and Alcohol (IAA)
5-National Petroleum Council (CNP)
6-Secretariat of Industrial Technology (STI)
7-Industrial Development Council (CDI)
8-Petrobras
9-Central Bank (BC)
10-National Bank for Economic Development (BNDE)
11-Bank of Brazil (BB)
12-National Monetary Council
13-National Security Council
14-Aerspace Technology Centre (CTA)
15-Brazilian Agricultural Research Corporation (EMBRAPA)
16-Foreign Commerce Bureau (Catex)
17-Foundation Getulio Vargas
18-Secretariat of Planning (SEPLAN)
19-The Special Secretariat of Supply
20-The State Secretariats of Agriculture, Industry and Commerce

Source:
Carneiro W. As distorcoes e as metas do ProAlcool, Journal do Comercio, Sao Paulo, 3 & 4 July 1983.

On the question of the case of the alcohol as a fuel, the policy at this stage was to adapt the Otto-Cycle engine for alcohol fuel. Industrial investment loans were provided at low annual interest rates, covering between 80-90% project costs (see Table 2.4). These early years represented the 'easy' phase of import substitution scheme. The policy was undefined and the role of the P.N.A. was not clear either. During those years the petrol prices in the international market remained stable, and, in addition, the discovery of off-shore oil near Rio de Janeiro in 1974, raised great hopes of Brazil becoming a large oil producer. The result was that little was done. By late 1978 opposition to the P.N.A. began to emerge. The Administration was divided in 'positivists' (the supporters) and 'negativists' (the opposers). Among the former were President Geisel, MIC, the sugar interests and some entrepreneurs who were benefitting from the programme; among the latter were the MME, Petrobras, The Treasury, the Central Bank and the Bank of Brazil.[19] Petrobras, who had supported the P.N.A. in its early years, began to feel vulnerable to a major alcohol programme. There exists a consensus among observers of the P.N.A. that Petrobras has been a major cause of the programme's delays. By failing to give its support it condemned the P.N.A. to an uphill battle, given Petrobras' key role in the energy sector. Nonetheless, despite these obstacles the National Alcohol Commission approved about 200 new alcohol distilleries and the MIC/STI laid out the basis for further technological developments in both agricultural and new end-use of alcohols.

2.2.2 Second Phase 1979-1980

The effects of the Iranian Revolution brought the P.N.A. much closer to reality. The decision to accelerate rather than to drop it was primarily due to the prospect of substantially higher world oil prices. By early March 1979, under President Figereido, the P.N.A. began to take shape and production and utilization of alcohol underwent marked changes. There was an expansion of the ProAlcool objectives aimed at reducing vulnerability of imported oil and a few political measures were taken to bring the P.N.A. into line with the Brazilian overall energy scenario. The decision-making centre for alcohol production was awarded to the MIC that was able to simplify the bureaucratic procedures of new distillery projects. For the first time the ProAlcool became part of the overall energy strategy. The alcohol sugar parity (i.e. the alcohol equivalent to be obtained from a determined amount of sugar) was reduced from 44 litres of alcohol to 60 kg. of sugar, to 42 litres of alcohol in June 1978, to 40 litres in January 1979 and 39 litres in October 1979 and 38 litres in May 1981.[20] The government agreed that the price of alcohol would not be greater than 65% of that of gasoline to compensate for the lower calorific value of alcohol.

The government and the automobile industry signed the first agreement for the production of alcohol cars in 1979. Production of alcohol was planned at 10.7 x 10^9 litres by 1985; increases of alcohol production were to be based on autonomous distilleries rather than the annexed ones. New incentives to the alcohol fuelled cars were introduced; alcohol/gasoline blends were extended to all national territory and the distribution network was consolidated. There was an expansion of sugarcane production to new regions, such as Goias, Mato Grosso, Minas Gerais, Parana, etc. There was a greater concern with environmental problems.

2.2.3 Third Phase 1981-1982

This is a period characterised by slowness of new distillery projects due to the economic crisis, caused amongst other things, by the world recession which hit Brazilian exports and caused lower estimates of economic growth. The policy towards the P.N.A. reflected this situation. The 8% growth planned in 1980 dropped to near zero in 1981. There was a lack of confidence that the government would not maintain the programme. Some high placed officials said publicly that the alcohol programme was inflationary and questioned whether the P.N.A. would be able to produce sufficient alcohol to meet continued increasing demand. Thus the initial sales boom of alcohol cars began to subside. Conflicting government priorities, varying economic policies, balance of payment problems, varying energy balances and fear of alcohol shortages played up in the national press, helped to bring out the situation.

2.2.4 Fourth Phase, or the Maturity of the ProAlcool[21]

In August 1983 President Figuereido officially approved the new goal of the ProAlcool: 14×10^9 litres to be achieved by 1987.[22] It represented a major policy commitment to the programme, so often questioned during the previous phase. The government increased alcohol blending to 20% in all national territory and gave further support to the automobile industry, particularly incentives to alcohol-powered taxis. In September 1983 Brazil celebrated the show "one million alcohol cars" in Brasilia with the presence of the nation's authorities.

Generally speaking, the programme is accepted as a major success and as one of the few genuine Brazilian projects. Most observers, accept the view that the ProAlcool has reached the "point of no return". The viability of the programme on the whole is not questioned, and the major criticism is on past mistakes. The present policy on energy self-sufficiency undoubtedly strengthens the ProAlcool further.

The maturity and viability of the P.N.A. was also recognized by the World Bank who provided a US $500 million loan for the third phase of the programme. It appears that the alcohol alternative is entering a new era with more clear political commitment and policy objectives.

2.3 The Productive Structure of the Alcohol Sector

A major criticism of the P.N.A. is that it is controlled by the large capital which has been in the main, the greatest financial beneficiary of the programme. The roots of the problem, however, have historical origins. The problem must be understood within the Brazilian agrarian structure as a whole, and more specifically within the socioeconomic structure of the sugar sector, Brazil's oldest industry. This has consisted, historically, of large properties controlled by a handful of families.

Indeed in Brazil the majority of the sugar mills are family properties, who represent one of the richest classes in the country. The whole sugar and alcohol industry is said to be owned by no more than 200 to 250 such families,[23] who tend to be related to each other (see e.g. 2.5). Even with the creation of the ProAlcool, the number of these families remains the same, for new distilleries represented either an expansion of the existing sugar mills or a new member of a family possessing a sugar mill becoming a new entrepreneur. Indeed, critics of the P.N.A. have argued that the programme has assisted this group to consolidate its capital and financial monopoly and also now extend it to raw materials and alcohol production technology.

No doubt that the alcohol policy, particularly in the first few years, has resulted in practice in the utilization of large public resources towards the benefit of large capital groups. This class was able to capitalize from the generous subsidies given to the alcohol distilleries. Table 2.4 illustrates well this point. The government provided between 80 to 90% financial loans for new distilleries, at very low interest rates, with repayment spread over a period of 12 years. These terms were even more favourable than those given under the rural credit policy (see also Table 2.1).

One must recognize the merit of these well found concerns, but at the same time it serves little purpose to assess this case in isolation. There are many other industries which are equally subsidized, including many State-owned companies. Alcohol subsidy is a controversial issue in Brazil, however one must not forget that so are petroleum derivatives (see 8.2.2). Foreign critics have noted the high subsidies given to the programme but such subsidy is not unique to Brazil. After all, as the Brazilians are quick to point out, the EEC agricultural policy (CAP), strains EEC resources almost to breaking point and in addition has

Table 2.4 Financial Conditions for the Installation of Alcohol Distilleries.

Financial Limits	Years	Interest Charges	Monetary Correction
Until December 1980:			
80% maximum for cane	12*	2-5% autonomous	40% of the difference of ORTN**
90% other raw materials	12*	4-6% annexed distilleries (depending on the raw material/region)	
From 1981:			
80% autonomous 90% Cooperatives	12***	---	55% for the Northeast, 65% for the rest-ORTN

Source:

Informações Básicas para Empresarios-ProAlcool, MIC/CENAL, May 1980, pp.15-20.
Banco Central de Brasil,Circular No.748, 22 April 1982

Notes:

* Plus 3 years grace period
** Obrigações Reajustáveis do Tesoro Nacional (Brazilian Treasury Bonds).
*** Plus 4 years of grace period.

had the effect of destroying Third World countries' sugar markets, unable to compete with heavily subsidised EEC's sugarbeet exports. Indeed, according to Hall, the cost of subsidies and of surplus of food in USA and Europe alone is over $60 billion annually.[24]

As for the concentration of capital, ProAlcool apologists also note that it is not very different to other sectors. Take, for example, the automobile industry, which is owned, they argue, by a few companies - General Motors, Ford, VW, Fiat, and Mercedes-Benz, so why do foreign critics never say anything? They also point to the large number of people who are dependent on this sector for employment. This, however, does not change the facts of capital concentration in this sector. A new and encouraging sign is that new sugar cane growing areas are being set up, which is opening up opportunities for non-traditional entrepreneurs to step in.

At the same time, a major shift away from State subsidies has occurred in the last few years, with many new projects being financed by private sources which have vitalised the ProAlcool. Despite the current economic difficulties, they have gained in confidence on the programme. In 1984, 67 of the 80 new projects approved (83.7%) with production capacity of 1.18×10^9 litres did not receive any State subsidies, whilst 13 (16.3%) were financed by the ProAlcool/BIRD. At the end of 1984, there were a total 146 projects with total capacity of 2.7×10^9 litres which did not receive State subsidies, as is further illustrated on Table 2.7.[25]

There is no doubt that the present productive structure of alcohol production - a reflection of the wider socio-economic system, leaves much to be desired and represents a political challenge to the new Civil Administration, more concerned with social issues. A suggestion put forward consists in separating the agricultural sector of the industrial phase to prevent further concentration and to further encourage the smaller producers. This would apply primarily to new projects.[26]

Table 2.5 illustrates the main economic groups in the sugar and alcohol industry. A major feature is the regional specialization and high concentration of the different economic groups, which includes both agricultural and industrial activities. The largest and politically most influential group is that formed by Copersucar - (Central Cooperative of Sugar and Alcohol Producers of the State of Sao Paulo), established in 1959,[27] which represents 41.2% of the sector assets and 43.5% of the sales, followed by the Ometto Group with 19.3% and 13.2% respectively. The Ometto Group has links with Stella, Biagi and Dedini, Ruete Oliveira and Zillo Zorenzetti in which this group represents 34% of total assets and 38% of total sales.

A further criticism of the alcohol sector, or rather against this powerful economic group, has been the tendency to build large distilleries without regard to the smaller ones. This has been defended on the grounds of 'economies of scale', which maintains that the larger the distillery the lower the cost, i.e. increasing production capacity from, say, 120×10^3 litres/day to 480×10^3 litres/day, the cost could be reduced by 60%.[28] This assumption has been openly questioned by Wright, who noted that 'many distilleries have been built at the wrong scale - too big to produce with simple technology of smaller plants, yet too small to benefit from the full scale economies of larger plants'.[29] The standard distillery being 120×10^3 litres/day. These large distilleries would have not, probably, been built, had the alcohol sector been controlled by a larg number of smaller economic groups.

The result has been a relatively high capital and technology unit -c. $30m, which only 260-300 Brazilian firms are regarded to have the necessary capital to develop. The disregard for the small distilleries is not due purely to economies of scale, there is a political root to it. During the first few years of the P.N.A. however, the government was mostly concerned to produce the largest possible amount of alcohol in the shortest possible time and excluded the small distillery from official credit. The result has been that only a few companies and private

Table 2.5 Economic Structure of the Sugar and Alcohol Sector
(Summary of major economic groups)

Group	Activity	Assests* (US$$10^6$)	Total sales* (US$$10^6$)
Copersucar	Sugar&alcohol Coffee	911.20	1 227.70
Atalla	Sugar&alcohol Coffee	99.80	21.40
Silva Gordo-Quata para	Sugar&alcohol, Forestry products	50.50	17.60
Ometto	Sugar&alcohol,agro-industry,vehicles	426.00	369.30
Dedril	Sugar&alcohol&equip. ment, metallurgy,etc.	19.70	25.00
Biagi	Sugar&alcohol,agro-industry,drinks etc.	53.60	99.20
Ruete Oliveira	Sugar&alcohol	48.20	47.20
Irmãos Franceschi	Sugar&alcohol	32.70	27.90
Zillo Lorenzetti	Sugar&alcohol,agro-industry	36.95	77.53
Resende Barbosa	Sugar&alcohol,agro-industry	20.70	48.30
Ribeiro Pinto	Sugar&alcohol,equip.	7.85	--
Marchesi	Sugar&alcohol, agroindustry	5.32	11.60
Purlan-Barrichecco -Coury	Sugar&alcohol	36.40	25.60
Marazzo	Food,chemistry,etc	27.00	81.20
Votamartim	Equipment,chem.etc	17.15	13.90
Scarpa	Sugar&alcohol, textiles	10.70	13.15
Otron	Sugar&alcohol, hotels, textiles	56.70	34.80
Wanderley	Sugar&alcohol	17.85	19.16

(Table 2.5 cont.)

Armando Queiroz	Equipment,banking, vehicles,textiles,etc	17.00	23.60
João Santos	Agroindustry,paper, cement, transport	16.85	16.70
Tavares de Mello	Sugar&alcohol,food	24.00	26.00
Jose Maranhão	Sugar&alcohol,agro. industry	8.00	10.00
A. Queiroz	Agroindustry,textiles	2.30	12.14
C.da Cunha	Sugar&alcohol	22.90	30.86
Pessõa de Mello	Sugar&alcohol	18.24	17.70
Pereira de Lyra	Sugar&alcohol	22.30.	18.30
Ribeiro Toledo	Sugar&alcohol	10.00	19.00
Ribeiro Orutinho	Sugar&alcohol	5.40	9.40
Others	Mills/distilleries	956.80	1 253.30
	Total..........	2 982.40	4 049.00

* 1980 US$1=Cr$52.60

Source:CEPAL: Caña de Azúcar, Producción de Alcohol y los Intereses de las Multinacionales en Brasil, E/Cepal/R324 August, 1982, p. 40, table 20.

groups have interested themselves in the small units - there are approximately 50 such distilleries currently in operation.[30]

Although there were problems with the small plants - e.g. fermentation problems caused by lack of qualified personnel, such as chemists, which such small units could not afford - the opposition of the traditional distillery owners to such units do not appear to be justified on economic grounds.[31] No doubt that the main cause of the failure to press the case for the small distillery, has been the lack of, or weak bargaining power of both the small distillery owner and the sugarcane planter.

However in the case of the small sugarcane plantation model, a predominant force seems to have been too the difficulty and financial risk involved in undertaking a distillery project without having the guarantee of sugarcane for processing. Contracts with a large number of small independent cane suppliers run a high risk of default, delay and lower production, all of which place the distillery operator under severe financial stress. As a result, together with government priority for rapid production increase of alcohol, alcohol production has almost exclusively been supplied with sugarcane from large plantations either directly or indirectly under the control of the distillery.

Other methods in support of the small cane producer were contemplated within the ProAlcool policy - e.g. incentives for setting up cooperatives. However incentives to small-medium farmers in cooperatives have not been an appropriate method for promotion their participation in the industrial phase of alcohol production, because of the nature of cooperativism. The purpose of cooperativism by definition and tradition is mutual assistance and not profits, which characterise capitalist organizations. The distillery requires ample capitalization and unified command factors which are more difficult to obtain through cooperatives. Further, according to Caron[32] cooperatives in Brazil tend to suffer from two main difficulties, (i) because they are in a sense contradictory to the broader economic system, they tend to become a private enterprise or disappear; (ii) the regional power given to the leader of the cooperative (this is particularly the case in the sugar industry) tends to generate small fifedoms which are less interested in improving the planters conditions than keeping their political power. Therefore the setting up of cooperatives proved to be more difficult than originally envisaged, at the same time it does not seem to be the alternative to land tenure concentration.

The political influence of the sugarcane lobby undoubtedly has shaped the ProAlcool - after all the programme saved this class from bankruptcy, to defend their own interests, firstly by making sugarcane the overwhelming energy crop, and secondly, by managing high state subsidies so they did not risk their own investment. At the same time succeeding to limit such subsidies to 100% domestically-owned capital. Though foreign firms were not banned from participating, lack of generous government credit effectively prevented them competing successfully with Brazilian firms. This included the alcohol equipment industry, strongly linked to the sugar interests, albeit the latter have more links with MNCs through contracts of licences and technology.

2.4 Alcohol Production

The alcohol production in the future will depend on many different factors, many of which are beyond the control of the Brazilian energy planners - e.g. world oil situation and new development in fuels technology. But the most influential factors would be, perhaps, political rather than technological ones.

The art of forecasting is full of difficulties and uncertainties, further obscured in Brazil by short-term policy objectives. Estimates vary from 16×10^9 litres to 60×10^9 litres of alcohol, depending on whether alcohol substituting for diesel oil is included. A reasonable forecast would be $25\text{-}30 \times 10^9$ litres, unless new raw materials - e.g. wood, could be used on a large commercial scale. Despite the existence of a large supply of land, over-dependence on sugarcane would become politically sensitive and perhaps unacceptable. Already very highly placed politicians have called for a maximum of 20 x 10^9 litres of alcohol to be produced from sugarcane,[33] and, as quoted above, the policy is for more diversified energy sources, including renewables.

Table 2.6 summarizes possible alcohol fuels demand (see also Chapter 6) for the 1990s, based on present trends. If present alcohol policy is not altered significantly, demand for alcohol fuels would be between 29-36 x 10^9 litres by the year 2000. This scenario is consistent with that of the MME for 1993 of 28 x 10^9 litres (see Fig 2.1). The scenario estimates that growth of alcohol fuels would be the same for cars, light and medium trucks, with a total fleet of 9.3 to 10.9 million alcohol fuelled vehicles by the year 2000. Economic growth estimates are zero for 1985; 7% annual growth for 1987-1990; 5% for 1990-1995; and from that date to the end of the century the economic growth is from 5-3%.[34]

These exclude other uses, such as chemical feedstocks, heating, pharmaceuticals, etc. The chemical industry is the most promising market, despite the fact that Brazil has made important natural gas discoveries which currently are cheaper than alcohol (see 7.5). Borges has estimated the demand for alcohol feedstocks in this industry at 1.5 x 10^9 litres in 1990 and 3 x 10^9 litres in 2000; and 0.5 x 10^9 litres in other industrial uses;[35] although other estimates quote much higher figures.

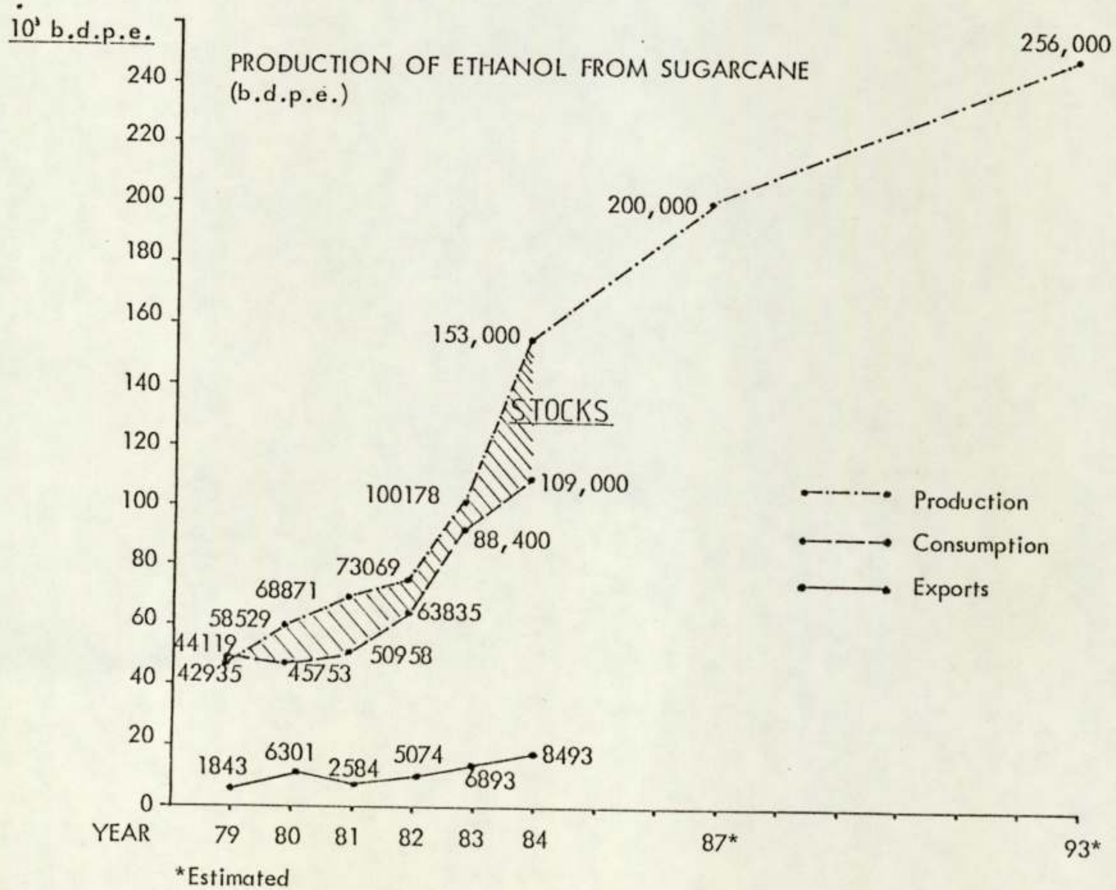
Currently, there exists a surplus of alcohol in Brazil which has steadily worsened, as can be seen also from Figure 2.1; from over 12 x 10^3 b.d.p.e. in 1980 to 44 x 10^3 in 1984. Therefore the alcohol industry is trying to find alternative uses and to diversify demand, e.g. in 1984 of the 8.1 x 10^9 litres of alcohol consumption, 81% (6.5 x 10^9 litres) were utilised as fuel. A more balanced supply and demand policy should be pursued if other alcohol spot markets, e.g. exports, cannot absorb existing surpluses. The present problem does not stem, however, from lack of demand, but from the fact that alcohol production has risen extremely rapidly. From 54.4 x 10^6 litres/year capacity approved in 1975; it jumped to 1.6 x 10^9 litres in 1976; 2.1 x 10^9 litres in 1980 and 1.4 x 10^9 litres in

Table 2.6 Possible Scenarios for Alcohol Consumption 1990-2000 (10^9) litres.

Year / Policy	1990	1995	2000
(i) Present policy	16-17.5	23.5-28.5	29-36
(ii)Policy based on reducing hydrated alcohol from 1986	7.9-10.1	7.5-7.9	6.7-7.7
(iii)Policy aimed at reducing alcohol cars from 1985	11:6-14.2	14.5-15.8	16.7-19.5
(iv)Use of hydrous alcohol in passenger cars only	11.8-13.1	14.5-16.8	21.9-25.9

Source: Pires Rodrigues,A.J.,Araujo J.L.,Límites ao Papel do Alcool na Política Energética, Energía e Crisis (Pingurlli Rosa Ed.) Vozes, Rio de Janeiro,1984,p.119

Fig. 2.2


10³ b.d.p.e.
PRODUCTION OF ETHANOL FROM SUGARCANE
(b.d.p.e.)
0
20
40
60
80
100
120
140
160
180
200
220
240
YEAR
79
80
81
82
83
84
87*
93*
*Estimated
256,000
200,000
153,000
STOCKS
109,000
100178
88,400
73069
68871
58529
63835
44119
42935
45753
50958
1843
6301
2584
5074
6893
8493
Production
Consumption
Exports

1984,[36] and reached a total installed capacity of 12.3×10^9 litres (40% increase annually from 1976-85), as can be seen on Table 2.7. Such rapid expansion could not be absorbed, particularly at a time of economic recession.

Table 2.7 shows some interesting features. Firstly in the rapid expansion of autonomous distilleries (i.e. those units producing exclusively alcohol which cannot produce sugar, as opposed to annex distilleries which produce both sugar and alcohol, therefore allowing greater flexibility according to the price situation) which represents 53.5% of total installed capacity. Secondly, in the expansion of sugar cane in non-traditional growing areas like the South, North and Centre-West, which just a few years ago did not have any production, and today represent 20.6% of the installed capacity. At the same time, Sao Paulo which was responsible for 65% a few years ago, had declined to 50% by the end of 1984, and the North-East, the second traditional sugarcane region, saw its participation reduced from 26.7% of the total production to 19.1%.

As for other sources of alcohol production, the IAA's data shows that in 1983, there existed 11 cassava-based alcohol distilleries, with capacity of 640×10^6 litres/year, though most of them have to stop, because the cost of raw material increased dramatically. This was due to increased demand for cassava caused by an increase in wheat prices after the I.M.F. forced the government to withdraw the wheat subsidies.

2.5 The P.N.A. Related Research and Development

As I have mentioned in the previous chapter, a major objective of the ProAlcool was to create the conditions for technological development in the field of alternative energy technology, chiefly from biomass. But in spite of the many efforts and resources channelled in science and technology, Brazil still lacks the necessary infrastructure. This can be a significant conditional factor for developing a strong renewable energy technology, since innovation activity is conditioned to the stage of scientific knowledge, the supply of inputs, and the

Table 2.7 Total Alcohol Installed Capacity on 31 December 1984 (10^6 Litres)

Region	No.Projects	Production Capacity		
		Financed by PNA	Self-financed	Total
North	8	92.0	60.9	153.5
Northeast	116	1 964.6	267.4	2 232.0
Southeast	316	4 948.4	2 193.4	7 141.8
- Sao Paulo	235	4 092.0	1 842.9	5 934.9
South	48	854.2	34.4	888.6
Centralwest	60	1 297.4	136.7	1 434.1
Total	548	9 157.2	2 692.8	11 850.0
Pre-PNA	33	---	---	418.4
Grand Total	581	---	---	12 268.4
Autonomous Distil (58.5%)	340	---	--- (53.5%)	6 565.2
Annexed Distil (41.5%)	241	---	--- (46.5%)	5 703.2

Source: CENAL, Relatorio Anual 1984, pp.9-10, tables 4,5,6.

level of technical and scientific skills embodied in people, market conditions and socio-political circumstances.

Since the creation of the P.N.A. research on new technologies has been mostly confined and coordinated by the STI of the MIC. In 1974 the STI created the Technological Ethanol Programme (PTE) with the objective of creating the necessary conditions for the development of alternative and renewable energy technologies as part of the IInd. PBDCT research programme.

The PTE research efforts concentrated on five major areas: (i) to improve raw materials for ethanol production; (ii) to develop the basic engineering equipment and processes for the production of ethanol; (iii) the development of an ethanol-based engine and also turbines; (iv) research on alcohol production by-products, e.g. stillage; (v) R&D on diesel substitutes, lubricants; (vi) ethanol chemistry.[37] In fact the PTE provided the technical know-how on which the creation of the P.N.A. was based.

After the creation of the ProAlcool, these objectives were expanded to include production and utilization of ethanol and new processes. The PTE was thereafter restructured to comply with these broader objectives, giving birth to the Programma de Pesquisa e Desenvolvimento Tecnologico da Biomassa (PPDTB) - Biomass R&D technology programme). The new policy adopted was more concerned with petroleum substitutes, as follows: (i) technological developments of production and use of ethanol; (ii) technological developments of production and use of charcoal and by-products; (iii) technological developments for the production and utilization of vegetable oil. In 1980 the STI organized, in Guarantingueta, S.P., a seminar to evaluate the achievements of the PTE at the end of which, it was agreed to include research on the socio-economic aspects of the ProAlcool and to greater diffusion of the programme's aims,[38] after some criticisms of the programme.

The IIIrd PBDCT has further stimulated R&D activities in this area (see section 1.5.1) particularly after the creation of PRONAB. Despite this research activity, the programme has been hindered by lack of funds, policy inconsistency and bureaucratic problems which have resulted in the loss of technology and export opportunities - e.g. cassave alcohol technology, as we shall see later. It is difficult to put any final figure as to how much is actually being spent on R&D in the ProAlcool given the large number of institutions involved, both private and state, and lack of co-ordination among these groups, together with the large and different areas varying from alcohol production to end-use. Table 2.8 summarises R&D expenditure from 1974-1984 by the STI, this amounts to $126.67m. approximately. This figure represents the overall expenditure, and it is difficult to know how much money went to research and how much has actually been spent on administrative and bureaucratic costs. An additional difficulty is the exchange rate which distorts real expenditure. As shown on the table, there has been a sharp decline in R&D expenditure in this area since 1981.

In 1984 the World Bank provided a loan to Brazil of $218.5m. of which $30m. was for financing R&D in the areas of production of raw materials, industrial processes, end-use, and for development of other alternative biomass energy sources, to be executed by the STI.[39] The new World Bank package for S&T represents, nonetheless, a significant step forward in the right direction (see Table 1.1). Albeit it is not clear at this stage how much money of this loan will be spent on ProAlcool-related R&D projects. Moreover a common complaint, particularly of the sugar and alcohol sector, is that there has not been any major effort by the Government to have a clearly defined R&D programme, concerned only to produce the largest possible quantity of alcohol, using existing capacity with the least possible investment. This may seem too sanguine a view, since the private sector in Brazil has distinguished itself by a lack of interest in investing in R&D, preferring to import the technology rather than to risk its capital on research.

There does appear to be a conflict of interests and priorities between the State planners and the private groups.[40] Nonetheless the private sector seems to

Table 2.8 Research & Development Expenditure on Biomass-Related Projects by MIC/STI, 1974-1984.

Year	Number of Projects	Value(10^3)* Cr$	US$	Research Areas
1974	2	4.69	0.76	Ethanol utilization, process
1975	4	7.57	0.93	technology, stillage, energy
1976	9	55.40	5.20	substitutes in general,
1977	23	102.40	7.24	technology transfer to the
1978	34	337.55	18.70	productive sector.
1979	43	474.01	17.64	Technological developments
1980	64	1034.06	19.62	in alternative energy
1981	77	2369.82	25.50	technology and energy conser.
1982	66	2581.88	14.30	vation.(Mostly biomass- related)
1983	71	7586.32	13.10	
1984**	5	7373.48	3.86	
Total	398	---	126.67	

Source:

1974-1978 compiled from: Desempenho da STI, periodo 1974-1978, Anexo I-Programa Tecnólógico Industrial de Alternativas Energéticas, STI/MIC, Brasilia 1979, pp.33-37, tables iv-2, iv-3 and fig. iv-1.
1979-1984, MIC/STI, Informe Estatistico 2 (9) 1984, p. 16.

Notes:

*Exchange rate is based on the average for each year, as table 1.3.

**According to CENAL, the STI had 50 projects in 1984 with an expenditure of $5m.(mostly in extraction, hydrolysis,sugarcane by-products) emissions control etc. In addition there were a further 43 projects related to sugarcane and food production.
CENAL Relatorio Anual 1984, CENAL 1985, p.40.

have been much more concerned with improving productivity and reducing costs, particularly in the capital goods sector, in the past few years, and are investing accordingly. A director of one of the major distilleries put it to me:

> "the way out of many of the problems facing the ProAlcool is to improve existing technology rapidly, and to develop new processes; to innovate fast so that we can overcome present low productivity."[41]

Certainly the private sector should be doing much more since the ProAlcool is financially under its control, though the government should use its powerful tool - official credit, to ensure that the country develops this sector for which Brazil has most of the technology, raw materials and human resources.

A point worth noting is that in the particular case of the sugarcane industry, many innovations have come from abroad. One reason being that the farming community has little trust in researchers within the formal R&D system (that is, from Universities, research institutions, etc.), considering them to be too theoretical in their approach to the practical problems, and hence the farmers take little or no notice of the advice given by those R&D institutions. Critics have pointed out that researchers within the formal system are more concerned to publish the results of their findings in specialist journals and receive recognition by their peers, who are generally located in the local university and abroad, than to solve practical problems. Further, these R&D centres have little regard for the informal R&D systems, and ignore traditional knowledge and dismiss the capacity of the informal R&D systems, for generating and adapting technologies. This system does not usually publish their research findings, probably because they are not part of the scientific community, and thus their motivation to carry out any experimentation is of a practical use only. In this way many small innovations may pass unnoticed. Velho points out that Brazil relies heavily on this kind of informal R&D system in the sugar industry and its capacity for adapting, improving and generating techniques among the components of the informal R&D system is considerable, but rarely taken into account by officials.[42] This should be borne in mind when assessing R&D efforts in the sugar and alcohol industry.

More recently the Ministry of Agriculture (MA) has also become increasingly involved in biomass-related R&D, mainly through Embrapa (Agricultural Research Corporation). The National Energy Research Programme (PNPE), the National Forestry Research Programme (PNEF) and ProOleo (vegetable oil programme), are all coordinated by Embrapa. There are complementary alternative energy programmes - somehow different to the ProAlcool, aimed at achieving greater energy self-sufficiency in rural areas.

The policy objectives of the MA can be summarised as follows: (i) to substitute petrol by alcohol; (ii) increase biomass production for energy use; (iii) reduce petroleum by-products consumption in the agricultural sector. The research priority areas are the production of sorghum, cassava, and sugarbeet. The ProOleo objectives were to expand production of castor oil, sunflower, peanut, etc.[43] The PNPE is a conglomerate of research projects of biomass production and utilization, which seems to be very ambitious.[44] Table 2.9 gives an indication of the main research projects undertaken or underway in in 1983 by Embrapa. Unfortunately no data concerning R&D expenditure is given in such a document. The table should be seem merely as an indication of Embrapa's involvement on biomass-related research. However, Table 2.10 gives a better indication of Embrapa's research expenditure. In 1973, e.g. Embrapa's research staff consisted of a mere 12 researchers and by 1982, this number had risen to 1578 (excluding technical support personnel) and a budget of $220m. Embrapa was created in December 1972 by Law No. 5951 with the aim to execute, co-ordinate and diffuse agricultural research.[45] As seen from the table it has grown dramatically since its foundation to the point where it is severely criticised by many academics and non-academic professionals of this area for hindering rather than promoting agricultural development. They claim it monopolises agricultural research funds, it is too big and bureaucratic. Embrapa's officials deny these charges, pointing out that the company has dramatically improved its research capability, e.g. they note the improved qualifications of researchers, most of

Table 2.9 EMBRAPA's Biomass-Related Research Projects. (Based on the PNPE 1983 Data).

Type of Research	Research Centres	Number of Projects
(a) Production of raw materials		
Amendoa (Arachis hypogaea)	5	15
Babassu (Orbinya spp.)	2	7
Sweet potato	4	2
Sugarbeet (Beta vulgari)	11	24
Sugarcane (Saccharum off.)	13	23
Castor (Brassica napus & campestri)	15	29
African palm "dende"	7	1
Forestry	15	5
Sunflower (Helianthus annuus)	19	68
Mamona (Recinus annuus)	5	13
Cassava (Manihot esculenta)	24	1
Sorghum (Sorghum vulgari)	24	12
(b) Research on transformation, utilization and energy conservation.		
Energy balance	10	3
Biodigestors	31	24
Solar and wind energy	25	6
Gas producer	12	6
Minidistilleries	28	10
Rural bioenergy systems	16	3
Food technology	23	2
Animal haulage	24	4
Hydroelectricity	4	-
(c) Economic research and system modelling		
Analysis and system modelling	11	6
Economic evaluation	6	12
Total	334	296

Source:

Compiled from the "Programa National de Pesquisa de Energia (PNPE), EMBRAPA, 1983.

Note: These figures must be seen as tentative estimates. Many of these projects may never mature.

Table 2.10 EMBRAPA:Budget,Number of Researchers,Support and Administrative Personnel, 1973-1982.

Year	Budget (US$10 ^{6})	Researchers	Support Personnel	Administrat. Personnel	Total
1973	---	12	7	47	66
1974	26.33	872	2 125	993	3 990
1975	56.04	1 040	2 356	1 416	4 809
1976	80.82	1 328	2 666	1 709	5 703
1977	98.65	1 311	2 678	1 696	5 685
1978	125.60	1 336	2 954	1 744	6 034
1979	154.12	1 448	3 191	1 935	6 574
1980	157.45	1 553	3 314	1 902	6 669
1981	182.95	1 576	3 340	1 948	6 864
1982	220.00	1 578	3 338	1 996	6 912
Total	1 101.96				

Source: Netto A.O, Yeganiantz L., Embrapa's Food-Bio-Energy Production Systems, EMBRAPA, Brasilia, 1982, p.16, table 5 whom today hold a Ph.D. degree.

There are other institutions involved in biomass research, particularly the MME, but the STI/MIC and MA are chiefly responsible and their R&D activities are the best and most accurate indications of what is happening in this field. There exists a general consensus among the ProAlcool observers that the programme is laying out the conditions for far reaching technological developments in the field of biomass technology. This is despite the fact that in many instances this technology can still be regarded as traditional - e.g. this is particularly so with sugarcane, but with good exceptions. Therefore, Brazil may truly master many of these technologies. Currently the cost might be regarded by some people as too high, but this must be the necessary price to pay for the development of an alternative energy technology for the future. The P.N.A. can be regarded as an 'open experiment' and as one of the most widely discussed and criticized programmes within and outside Brazil. This did not happen with other, equally important projects.

Biomass related R&D projects have declined in the past few years due to the economic recession. This trend needs to be altered if the conditions for these technological developments are to be sustained. Critics have argued that Brazil is involved in too many of such projects (some of which are too vast and costly) which cast some doubts in Brazil's, technical and financial capacity to fully develop such technologies on a large commercial scale. A more realistic option would consist of selecting certain areas and defining priorities more clearly and to allocate R&D funds accordingly. This policy seems to be at least being put into practice with the reformulation of PRONAB's original objectives.

In short, many of the problems of which the ProAlcool has been accused, are ill-founded. In so far as these have been found to be deeply rooted in the genuine nature of the socioeconomic structure of Brazilian society, particularly agricultural structure. As a reflection of such structure the programme has inevitably benefited more the large and powerful groups within this sector. This was further aggravated by governmental agricultural policy. In the past 40 years Brazil's rapid industrialization has been partly financed by commodity exports, heavily subsidized because of the need for hard currency. This was due to the fact that it is an area where Brazil could compete internationally. The higher prices received by farmers and the devaluation of the 'cruzeiro' since 1983, further stimulated export and domestic recession. The pledge given by the new Civil Administration to change agricultural policy, towards food production for domestic consumption rather than export, if fulfilled, represents a very significant improvement.

As for research commitment, it is worth noting that despite its short history, the P.N.A. has been subjected to far too many fluctuations and policy inconsistencies. The continued indefinition of goals, credit lines, regionalization of production, etc. have been the outcome of keen competition between different groups within and outside the political arena for the beenfit of controlling much strategic national programme, further complicated by lack of a clear global energy strategy. This situation has been a major hindering factor in executing R&D projects[46] since it has been very confusing for researchers in the absence of clear goals. It was difficult to visualize future problems and needs and consequences of the ProAlcool, and furthermore it has been difficult to plan research activities and even to choose what kind of problem should be studied. Yet, at the same time, no one could deny the success of the programme on many technical fronts.

Policy consistency and clear goals are fundamental pre-requisites to achieve R&D results. Having reached a maturity stage, and with many of these problems settled, many of these difficulties should be overcome. Yet there remains uncertainty on what policy the new administration is likely to follow, though little change is expected. So far a clear policy does not emerge, uncertainty will continue to hinder progress towards new developments, until clearer goals are set.

CHAPTER 3

FEEDSTOCK PRODUCTION: PROBLEMS AND PERSPECTIVES

Introduction

Raw materials constitute a high proportion of the economic cost of ethanol production - c. 60-70%. Reducing costs through increased productivity and efficiency is an economic imperative. In this chapter I assess the main problems and perspectives in feedstock production. I consider some of the technological alternatives for increasing productivity of energy crops under consideration and the problems related to sugarcane, cassava, sorghum and forestry (wood-ethanol/methanol), the limiting role of vegetable oils and the implications for the economics of ethanol production in Brazil, should sugarcane bagasse become a commercial reality.

3.1 General Considerations

To improve productivity of biomass, a key factor in Brazil, requires an understanding of the complete process; therefore improvement relates to basic physiological processes, selection and breeding techniques and aspects of crops management. Except in the case of sugarcane, capacity appears to be a limiting factor in Brazil, at least in the short term, because agricultural research on the whole is far behind that of industrial countries.

At the same time, whilst Brazil might lead the world in large-scale industrial alcohol production, it remains a fact that sugarcane productivity is among the world's lowest (although it is true that its production costs are amongst the lowest too). There are enormous regional disparities, the modern production system of Sao Paulo contrasts sharply with the North East, where cane is still transported on mule back and where the 'usinero' (mill owner) often continues to show little concern for improved efficiency and managerial skills.

There are also serious problems with skilled personnel to attend the new requirements of the ProAlcool, particularly chemists, fermentologists, technicians and other skilled staff. This stems from two major reasons: (i) poor salaries, and (ii) lack of, or low, prestige associated with working in rural areas together with problems caused by lack of amenities. For example, in early 1984, 22.24% of the distilleries in Sao Paulo (SP), the most advanced in the country, did not have any agronomist and 31.4% had only one, often involved in administrative work.[1]

Land availability is not a serious problem,in theory, given the existence of large tracts of unutilized arable land. In practice, however, things are different and investment costs in the future would be much higher. According to Pamplona[2] to achieve 14.3×10^9 litres of alcohol by 1987/88 would not demand more that 1% of the suitable arable land, but such expansion would have to take place in poorer soils and furthermore would require more investment in soil preparation and infrastructure. In addition, as the capacity of the annexed distillery is near saturation point, new expansion would have to be based on independent distilleries which require higher investment. Until now, total production has been mostly achieved by expansion rather than increase in productivity; this trend must be reversed.

However, with improvement in management techniques, the introduction of new varieties, more resistant to drought, and the utilization of stillage as fertilizer 'in natura', new lands would be opened up which until now have been regarded as unsuitable for sugarcane, and hence reduce investment costs. The generally accepted view that sugarcane requires good quality soil is being disproved by recent experience.

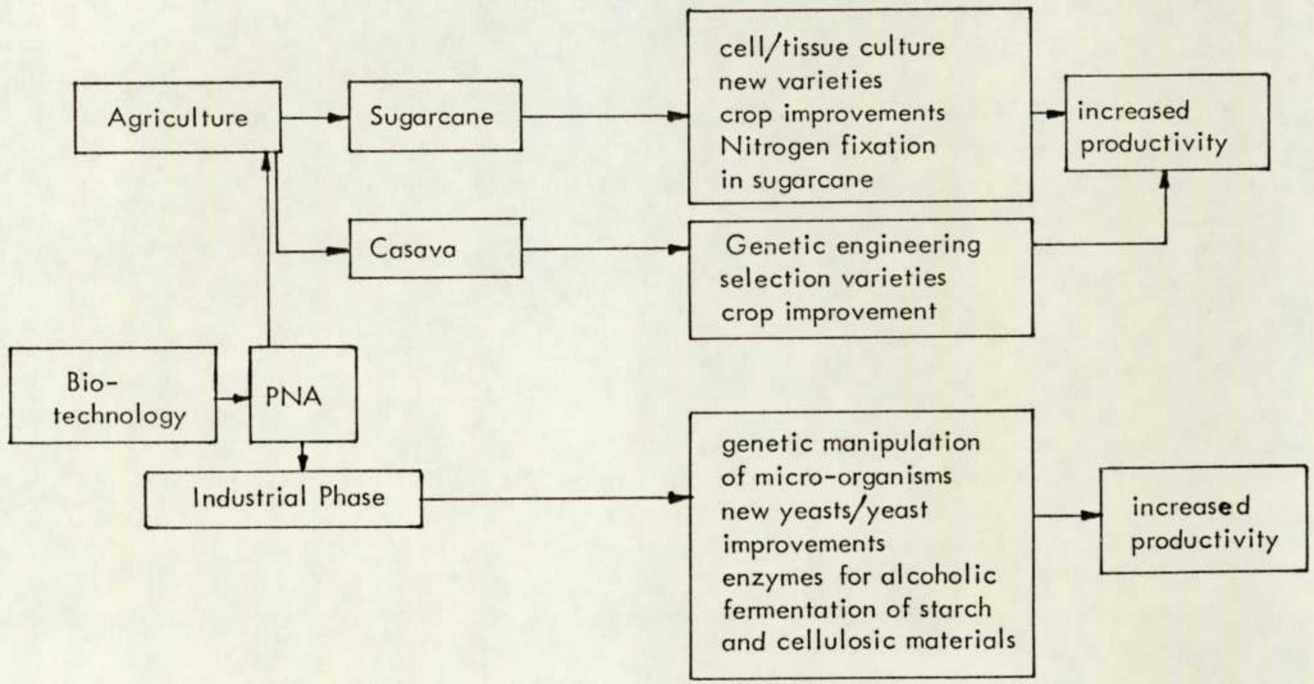
Studies by Copersucar suggest that when sugarcane is properly managed and new varieties suitable for poor soil introduced, good quality land is not necessary. In the 1983/84, 10% of Copersucar's planted area was in this type of soil, so far with good results; which has encouraged the cooperative to set up the 'Projeto Cerrado' with the aim of producing new varieties suitable to the cerrado's conditions.[3]

This would therefore ensure that energy crops expansion, chiefly sugarcane, occurs throughout the agricultural frontier and on what is pasture land - currently of an extensive nature and of very low productivity, Such partial substitution could facilitate the modernization and increase production of meat and dairy products.

A major problem is how to increase productivity in the small plantations. A STI study found a strong correlation between low productivity and size of the plot of land, i.e. the smaller the plot the lower the productivity. In 1980 the productivity of such plots was 28.4 ton/ha. for those under 10 ha., 41.1 ton/ha. for those between 10 to 100 ha., and 45+ ton/ha. for those of 100+ ha.[4] These findings have been recently challenged, particularly in the case of S.P. where productivity of the small producers was reported to be greater than the large plantations.[5] One of the reasons for such poor performance of the small plots is the undercapitalisation of the small farmers.

The rapid implementation of biotechnological and genetic engineering techniques, together with better management practices offers the best hope of achieving greater efficiency in the short and medium term. This is particularly the case with sugarcane, and to a lesser extent with cassava, where Brazil can make important advances in the short term. Fig. 3.1 illustrates the possible biotechnological applications on sugarcane and cassava, to improving productivity in both agricultural and industrial phases..

Fig. 3.1 SHORT-TERM APPLICATION OF BIOTECHNOLOGY IN THE ENERGY SECTOR IN BRAZIL



3.2 Technological Strategies

Despite the large number of plants under investigation, as possible sources of alcohol production, only a few can realistically be considered as serious candidates. These are: sugarcane, cassava, sorghum, wood and vegetable oils. Sugarcane is, of course, the source of ethanol production in Brazil on a commercial scale at the moment, the rest are used on a small experimental scale, if used at all. In the longer term some consider the most promising to be forestry (wood), provided that the technology can be developed for large scale industrial processes.

So far the best and most detailed study on the ProAlcool was carried out in 1980 by the STI/MIC, called "Previçâo e Analise Tecnológico do Alcool"[6] which went to great lengths to envisage a number of possible strategies to improve and to assess the development of the P.N.A. A large team of researchers from many disciplines took part and all major possible implications were considered - social, economic, energy, environmental and technological, up to the next 10 to 20 years. As for the raw materials, eight main technological strategies can be considered until the year 2000, based mostly on sugarcane, cassava, sorghum and wood.

(1) Sugarcane 'unchanged' - in which 80% of the sugarcane would be supplied by the small owners and 20% by independent sugarcane producers. Production would continue the same, without significant technological improvements or innovations.

(2) Sugarcane with Technological Improvements - production to be controlled by the alcohol producers in land owned by the distillery. Technological improvement would include mechanization and new sugarcane varieties and use of stillage as fertilizer. This is largely the case, particularly in S.P. and new sugar growing states.

3) Sugarcane with Technological Improvements - the same as strategy (2) but

60% of sugarcane to be supplied by independent producers and 40% by the distillery.

(4) Cassava with Intermediate Technology - this strategy foresees cassava cultivation without any improvement (12 tons ha./year) 50% produced in medium-size farms and 50% in small plots. This productivity can be regarded as too low for large utilization of cassava.

(5) Cassava with High Technology - new varieties resistant to diseases and better use of fertilizers and productivity to be increased to 20 tons ha./year. 40% to be supplied by medium-size farms and 60% by small ones.

(6) Sugarcane and Cassava - distilleries to use both crops, 43% sugarcane (strategies 2 and 5) and 57% by small cassava producers. Both agricultural and industrial processes to be improved.

(7) Sorghum - production increased to 90 ton/ha., two harvests per year with modern production methods.

(8) Wood - Production in highly developed plantation system. This is one of the most promising in the medium term, but it is not being regarded as feasible in the short term.

Table 3.1 summarizes the main characteristics of these strategies (it includes five strategies only since sorghum has been excluded due to the similarities with cane, as we shall see later). This table is based on the SIT/MIC study, with some adjustments. The potential return on research expenditures in the alcohol field is very great. In moving from, say, 'unchanged' to 'improved' technology of the strategy, the production cost per litre of ethanol could be halved and the productivity of the agricultural area doubled, and further, to increase the number of operational days/year it is possible to reduce significantly the number of distilleries and the land area needed to attain the ProAlcool goals. But, as we shall see below, the table does not represent the whole potential, particularly with regard to cane and cassava.[7]

Table 3.1 Main Coefficients of the Technological Alternatives.

Alternative	1 Cane Unchanged	2 Cane Improved	3 Cassava	4 Cane*	4 Cassava	5 Wood
Agricultural Productivity (tons. ha./year)	60	80	17.5	80	17.5	15
Total Sugar Content(Kg./ton)	150	170	330	170	330	330
Industrial Yields						
-Preparation (%)	91	97	98	97	98	72
-Fermentation(%)	83	90	90	90	90	90
-Distillation(%)	94	98	98	98	98	98
-Lossess Factor	0.93	0.97	0.96	0.97	0.96	0.99
Overall Industrial Yield (%)	66	83	83	83	83	63
Alcohol Volume per ton of Biomass (litres/ton)	64	92	177	92	177	134
Days of Operation	200	300	300	200	100	134
Overall	3840	7360	3098	5046		2010

Source:

Doin P A, et. al. Technological Strategies for the Industrial Phase of Ethanol Production in Brazil, Proceed. V International Symp. of Alcohol Fuels Technology, Auckland, New Zealand, 13-18 May 1982, p.I-166, table 2.

(Note: this table is a summary of the main coefficients only)

* Sugarcane plus Cassava.

3.3 Sugarcane

Brazil has been a leading world sugarcane producer for nearly four centuries. As early as 1534 the first sugar mill was built in Pernambuco; and in 1870 the Imperial government provided capital to industries for setting up sugar mills. Separation between the agricultural and industrial plants began to take shape with the latter tending to dominate the former. Today it is the overwhelming source for alcohol production, due to such historical traditions, highly mature technology, infrastructure and, of course, due to the political influence of the sugarcane lobby.

Sugarcane is grown predominantly in large plantations. The most common production system results in three harvests within four years. Land preparation is largely mechanized whilst planting and harvesting is labour intensive. Manual harvesting is preferred because the cane has less impurities - very significant in the fermentation step.[8] Irrigation is almost non-existent if seed cane nurseries are excluded. The harvesting and milling season generally extends from 150 to 180 days/year from September to April in the North-East and May to December in the Centre-South.

Productivity shows wide variations and is alarmingly low in some regions. Recent data shows that average productivity was 47-60 ton/ha. in the 1972-1982 decade, despite the improvements of the last few years, although estimates vary considerably.[9] In S.P. this is over 70 ton/ha., still quite low if compared with 120 ton/ha. in Colombia; c.90 ton/ha. in Egypt and South Africa, for example. These large variations in productivity are due to the different cane growing areas, investment levels, technology, lack of new and better varieties, etc.

The sample of Table 3.2 illustrates well these differences. In S.P.

Table 3.2 Agricultural and Industrial Productivity of Autonomous Distilleries in the Centre-South Region,1975/76 and 1982/83 Harvest.

Harvest	Sao Paulo		Parana		Mato Grosso do Sul	
	AP*	IP*	AP	IP	AP	IP
1975/6	59.4	58.2(1)**	-	-	-	-
1976/7	70.8	52.1(1)	-	-	-	-
1977/8	78.0	59.3(3)	90.6	34.8(1)	-	-
1978/9	54.5	60.6(5)	46.0	41.9(2)	-	-
1979/80	69.6	63.4(10)	91.6	59.2(4)	55.2	57.5(3)
1980/1	68.1	65.0(14)	103.1	62.5(6)	49.2	62.5(3)
1981/2	66.9	69.0(21)	81.4	66.9(8)	36.6	52.7(4)
1982/3	72.6	64.8(41)	81.1	55.2(11)	43.4	50.6(6)

Source: Based on Pamplona C. ProAlcool: Impacto em Termos Técnicos -Económicos e Sociais do Brasil, IAA/MIC, 1984, p. 40, table 22.

Note:* AP-Agricultural productivity; IP= Industrial productivity
** Numbers between ( ) indicate number of alcohol distilleries in operation.

productivity (ton cane per ha.) increased from 59.4 ton/ha. in 1975/76 to 72.6 ton/ha. in 1982/83, but the same cannot be said of industrial productivity per ton of cane. It fell from 69 l/ton in 1981/82 to 64 l/ton in 1982/3. In Parana the maximum productivity was 103.1 ton/ha. in 1980/81, but alcohol/ton was just 62.5 litres. In Matto Grosso do Sul (M.S.) industrial and agricultural productivity differences are still more marked.[10]

The productivity statistics appear very uneven and show extreme variation from year to year and from one region to another. These differences stem from many and varied factors ranging from climatic influences, soil quality, sugarcane aging, statistical errors, etc. This simply illustrates the difficulties in assessing national average productivity[11]. Where significant advances in sugarcane production can be demonstrated, there is controversy as to the extent to which these are due to new varieties and managerial techniques or due to biological factors.[12] This is because an increase or decrease in sugarcane productivity is very much a function of the plants' age. Because of the continuous expansion of plantations in recent years, there is an increasing proportion of young vigorous plantations.

Sugarcane expansion has proceeded essentially within an extensive production system in which three key factors were largely neglected - viz. land, productivity and efficiency. In support of this philosophy were the relatively low cost of the production factors; great availability of cheap and fertile lands and abundant labour supply. An additional factor was the low market prices of sugar and great market variations. That the room for improvement in sugarcane production is quite large, was clearly shown in a symposium organized in Campinas, S.P. in 1982, whose findings a re summarised on Table 3.3. The potential productivity increase is 80 ton/ha. for the small farmer (c.55 ton/ha, average in 1981) to 150 ton.ha. (from 90 ton.ha, in 1981) when sophisticated production techniques are used. At the same time

Table 3.3 Potential Productivity of Sugarcane in Brazil. (Ton/ha. per year)

	Average*	Potential
Small farm	55	80
Large farm	70	90
Low fertility farm	50	70
High fertility soil	80	110
Low rain fall	55	70
High rain fall	80	100
Low technology	50	60
High technology	90	150

Source: Anon. Quoted from a Symposium of Biomass Substitutes for Liquid Fuels, Campinas, S.P. 4-12 February 1982, (Organized by STI/MIC).

* Average productivity estimates tend to vary according to sources.

production costs could be cut by c.20%. Some experts even believe that 200 ton/ha./year and an increase of sucrose content to 20% is possible in the medium term. This seems to be an over-optimistic assumption, since such high productivity could only be achieved in small and highly fertile, irrigated areas, far from the national reality. 90 to 110 ton/ha. per year seems to be a far more realistic objective.

According to the STI/MIC study, three major improvements in the sugarcane agroindustry are judged to be of critical importance: (i) increased productivity of fermentable sugar/ha.; (ii) an increase in the number of days the distillery is in operation; (iii) improved efficiency of the industrial processes. Improved productivity of fermentable sugars/ha. could come from an increase in the sugar content of harvested cane - currently 13-14% by weight. An increase to 17% over five to ten years is quite possible by using new improved varieties and better management. The increased productivity judged feasible over and medium term (Table 3.1) would raise the average productivity from about 65 tons/ha. (note: average productivity varies), three harvests in four years, to 80 tons.ha. per year. New improvements would permit an additional rate of growth (four harvests in five years), raising productivity per hectare from 72.7 to 101 tons/ha., an increase of 39%. It is also possible to increase distillery operational time to 200 days/year, utilizing new varieties and management practices, to 300 days/year if production and milling during the 200 days season are increased by 50% with the incremental cane juice concentrated to about 60 $\underline{^{o}}$Brix and stored for later dilution and use during the 100 days after the harvesting season has ended A third major area of improvement concerns the efficiency of the various steps in the industrial processes which can reduce largely investment per litre of alcohol (see Chapter 5).

These three improvements when considered together could represent a remarkable gain in overall productivity with substantial savings in investment cost production and represent a key factor to reducing the total land area required for alcohol production. The development and adoption of these measures imply an increase in the alcohol yield from a ton of sugarcane of about 45%, increasing from 65 litres per ton to 90 litres per ton. As a result, productivity per hectare raises from 3600 litres to 7200 litres, an increase of 100%.[13]

Though it can be achieved, it is certainly an ambitious task, albeit the P.N.A. is forcing the pace of change; but there remain serious problems to overcome. The sugarcane producers are, on the whole, very conservative and resistant to change although they do have a great understanding of traditional methods of sugarcane production. The new comers, though more open and willing to change and adopt new methods, lack the experience, albeit they are learning quickly. Many of them came from outside the agricultural sector, attracted by the new opportunities and incentives only. Production methods and technology are not up-to-date, complicated also by the lack of knowledge by many new sugarcane growers.[14] Poor RandD in agriculture is doutbless a serious problem in Brazil as well as many other LDCs. It is quite clear that many genetic improvements are needed: disease control, planting methods improvements, etc. Better information and and technology transfer system to the farmer, and great incentives to the skilled workers also requires greater and urgent attention.

Agricultural research is an old problem area in Brazil. Because of the continuous incorporation of new lands, there has not been any serious pressure to increase productivity, and thus research tended to become increasingly isolated from the real needs of the sugarcane producers. Further, the lack of a governmental research programme of any significance, forced the large farmers to introduce new techniques (the small ones could not afford to do so), mostly capital intensive techniques, such as mechanization, without being properly adapted to the medium. This has resulted in the introduction of technology unsuitable to the local conditions.[15] The first official co-ordinated research programme began with Planalsucar who provide technical support preferently to the small sugarcane producers. Many significant productivity increases have already been achieved thanks to the efforts of Planalsucar. The P.N.A. however, raised too many expectations - a number of experts were predicting a revolution in productivity in the short-term, which, of course, did not materialize. Nonetheless, once the significant research which commenced in the late 1970s, begins to produce results, one can reasonably expect greater returns in many areas of sugarcane production.

Planalsucar was officially set up by the IAA in 1971 and became operational in 1972, with the aim of carrying out research on sugarcane. Today's policy is very much linked with the ProAlcool's objectives. It has over 30 experimental centres nationwide, some of them of extremely high standards, which stand among the world's best. Planalsucar deals with almost everything related to sugarcane - from disease control, to education/training, fertilizers, introduction of new varieties, development of new yeasts for alcohol production, diffusion of new technology,etc.[16] Critics, however, point out that Planalsucar is slow-moving, administratively costly to run, and that it produces few practical results. Copersucar has been a major and dynamic leading research organization, which, unlike Planalsucar, is privately owned. Copersucar's Technology Centre in Piracicaba, S.P. is the leading sugarcane research centre in the country. It has 10.000 m^2 research area facilities. Recently the Centre merged all other units in a new Central Analysis Laboratory.

3.3.1 Genetic Improvements

There were 75 commercial sugarcane varieties in 1980 in the State of S.P. alone, though 57% of the planted area was represented by two varieties, the NA56-79 and the CB41-76. More recently six new varieties were introduced by Planalsucar of the series RB and 12 by Copersucar of the series SP which has increased productivity over the old ones by 30%. The introduction of the NA56-79 variety has played a significant role in the rapid expansion of sugarcane production during the first few years of the ProAlcool because it is robust and adaptable to new and different soil conditions.

Yet despite these recent advances, change will not come early because of deep-seated problems stemming from the historically low priority given to research, unlike other major sugarcane producing nations and despite the great economic significance of this crop. Genetic improvement and the introduction of new varieties, are recent phenomena, although the first steps date back to the 1930s, when the CB (Campos-Brasil) variety was developed, and the IAC by J.M. Aguirre.[17] But on the whole such activies were on a small scale and far from systematic large-scale and well-planned research. Such programmes did not start until the late 1960s and early 1970s. It was with the introduction of the P.N.A. that a major effort began on plant genetic improvement, though most of these researches concentrated on the traditional selection of varieties.[18]

Copersucar has a large programme of genetic improvement, of special significance is that of Camamu (Bahia) Centre, where over 1800 different seedlings of the SP variety are kept.[19] The development of a new variety by the traditional method is an arduous and time consuming process - it takes approximately ten years to develop a new commercial variety. The selection of a new variety depends, of course, on local conditions, soil, climate, etc.

3.3.2 Cell/Tissue Culture

The development of cell/tissue culture techniques, is seen in this sector, of extreme importance in assisting reduction of the time span and improving the quality of the new varieties. Already important advances have been reported elsewhere in sugarcane, particularly in Hawaii, Australia, Taiwan and Fiji, in disease resistant varieties.[20]

Although one must recognize that there exists a great difference between the laboratory and the farmer's field, new plant genetic engineering techniques could revolutionize this area of research although some scientists maintain that present techniques are likely to remain the same for the forseeable future.[21]

Certainly this is becoming an important priority research area in Brazil, particularly in S.P. State. Tissue/cell culture is becoming a basic technique for plant propagation and an excellent auxiliary tool in the breeding of economical plant species. It offers a good system for the understanding of the biological physiological and genetic processes occurring in the plant cells and opens and enlarges the routes for the potential applications of the biological and genetic techniques. There exist in Brazil five main research centres actively involved in cell/tissue culture in sugarcane - CENA, ESALQ (Higher School of Agriculture), Planalsucar, Copersucar and the I.A.C. (Campinas Agronomy Institute), plus some other university departments working particularly in disease/pest control.

The CENA and ESALQ have been using the CB41-76, IAC48-65 and the NA56-79 varieties, cultivated in 'vitro' to produce a new variety resistant to diseases, so far with very good results.[22] Planalsucar also has a very large cell/tissue culture laboratory. The project aims to develop new varieties resistant to diseases and flowering-control; new varieties more suitable to alcohol rather than sugar production; and rapid breeding techniques.[23] Copersucar's major efforts in tissue/cell culture are on disease-free new varieties. Of special significance is the work done by Pavan's team of the

Genetic Department (University of Campinas) on the virus granulose of 'Diatrea saccharolis'.[24]

3.3.3 Nitrogen Fixation (N_2 Fix)

With increasing fertilizers cost and the constant need to increase agricultural productivity, N_2 Fix research is becoming increasingly important for crops production. In the case of sugarcane, its capacity to fix its own N_2 has been suspected for years. For even in soils of poor nitrogen levels cane crops have been continuously grown without fertilizers for over 50 years without much decrease in yield. Although some N_2 could be derived from soil, from fertilizers or from roots in the original plants, evidence so far strongly supports the argument that sugarcane fixes its own N_2.

A reasonably conservative estimate of biological N_2 holds that at least 17% of the total plant N_2 is fixed by the plant itself.[25] Although the commercial exploitation of N_2 Fix in sugarcane may be still a long way off, it may, nonetheless, be of great economic value. N_2 Fix in sugarcane is being investigated in the CENA by the Ruschel's team. According to some of their findings as much as 30% of the total fertilizers could be saved.[26] This is particularly important in areas like the 'cerrado' where large quantities of chemical fertilizers are needed. The Ruschel's team use different types of cultures in which different species of microorganisms were isolated capable of nitrogenization activities in the sugarcane plant - Azotobacter, Beijerinckia, Derxia, Caulobacter Clostridium, and Vibrio Dacillus. [27]

3.3.4 ^{o}Brix.[28]

Productivity for ethanol production should be evaluated in terms of fermentable sugars/ha. - that is, total fermentable sugars productivity (TFS) per ha./year. However, in Brazil the prevailing payment system to the farmer -

contrary to most large sugarcane producing countries - was according to weight rather than $\underline{^o}$brix. This has meant that there was little incentive to improve sugarcane quality. Indeed, that system has been regarded by experts as a major stumbling block to sugarcane improvement in the past. It is reckoned that this change would revolutionise sugarcane production in Brazil in terms of productivity with at least 15-20% increase in the medium term.[29]

Despite the fact that the first attempts date back to 1941, such changes were resisted by the farmers and not until 1978 did the IAA managed to introduce the new payment system in Alagoas. It was not until 1982 that it really began to be consolidated in the traditional sugarcane producing states of S.P., Rio, Permambuco and also in Alagoas. Payment according to sucrose content is expected to be fully implemented by 1988/89 harvest. This slow implementation process is not only due to the sugarcane growers' opposition, but also due to problems with the equipment and lack of qualified personnel for laboratory analysis.[30] The new process is also forcing the sugarcane producers to supply the cane free from impurities, which was previously a serious problem.

3.4 Casssava ('Manihot esculenta')

Although this crop offers the greatest potential, as mentioned above, it is hardly used, despite the fact that when the P.N.A. was created it was considered a priority crop. A few reasons are worth recalling: (i) lack of industrial experience with large-scale units; (ii) the political influence of the sugarcane lobby, who feared competition from cassava for financial resources - although the cane producers deny it and argue that they will use any economic crop. Cassava presents many socio-economic problems. It is cultivated in small plots with very low productivity - 12 to 14 ton/ha.; (iii) as Petrobras became involved early on, the sugar lobby feared that this state monopoly would control alcohol production through its participation in cassava; (iv) lack of experience with large and intensive cassava plantations.

Almost a decade after the creation of the ProAlcool, few cassava distilleries exist and those that were operating had to stop early in 1984 because the cost of the raw material was too high. With the withdrawal of wheat subsidies (which the Brazilian government had to do under pressure from the I.M.F.) there was a shift back to cassava demand which resulted in over 100% price increase. The experimental plant of Curvelo, M.G. provides a further good example. Since the plant was set up in the late 1970s, it has been plagued with socio-economic and political problems, in which vested interests tried to prevail. To start with, the site of the plant was politically influenced and although this seemed to have been justified, the area did not have the necessary conditions for such large plantations (200 tons of cassava roots per day). Secondly, it has led to Petrobras running the whole operation[31], who subcontracted much of the work to third parties. These third parties were more interested in land speculation than cassava production. Petrobras itself lacked the necessary experience for such a task. Most observers blame Petrobras for most of the problems accrued in Curvelo's plant.

Though some technical problems did arise, partly because the plant was put on stream too rapidly and it was not possible to check all the technical details, no serious technical problems existed within the plant.[32] The problems appear to have been basically political, agricultural and of a planning nature. In addition no proper measures were taken to ensure disease control. Plant seedlings were brought from different parts of the country already infested with bacteriosis - a disease caused by '<u>Xanthomonas manihatis</u>', which caused very serious problems. As a consequence of all these problems the Curvelo experiment has appeared as a failure when the truth of the matter is that it never had the chance to be fully and properly tested. So far as one can tell, Petrobras has finally sold the Curvelo plant to private interests.

Such a situation has created serious difficulties for the development of cassava-based alcohol production technology, chiefly for exports. Since the 1979 Vienna Workshop on Fermentation Alcohol[33] where the Brazilian representatives presented significant advances in this field, there has been a surge of interest in many developing countries[34], on which Brazil has failed to capitalise. This is despite of Brazil's historical experience with alcohol from cassava which dates back to 1934. Japan is filling this gap, particularly in South East Asia, but without the necessary industrial experience, but with sufficient financial resources.[35]

Cassava can be transformed into alcohol either in fresh or in sun-dried roughly grated form. The process for grating and sun-drying is simple and inexpensive, well suited for small farming operations. The dried grating can be stored for long periods of time without problem, and given their high content, can be transported over long distances economically. Cassava is one of the world's greatest root crops - is a hardy perennial about 9 feet (2.5 metres) high. Its roots, the source of starch, are quite large, some 3 feet (1 metre). In Brazil a plant 10-12 months old can produce 6 to 8 kgs of roots and 15 kgs in two year old plants. In a culture of 15000 plant/ha. productivity can reach 100 ton/ha. In Mato Grosso do Sul productivity has reached 60-80 ton/ha. although as much as 300 ton/ha. in fertile soil has been reported.[37] In Australia the average productivity is 35 ton/ha. Yet it is precisely low productivity that is the chief obstacle in Brazil - 12-14 ton/ha. on average, though with a wide degree of variability. With available varieties and current technology, production can reach 18.5 ton/ha. in medium and small plots. In S.P., which is the state with the most advanced production techniques, productivity increased from 16 ton/ha. in 1962 to 19 ton/ha. in 1975[38] and 22 ton/ha. in 1984.[39] However, cassava plantation is S.P. have been declining, replaced by wheat, soya-bean cultivation and because of disease problems.

As scientific knowledge increases and new and more highly productive varieties are developed, it is estimated that the national average productivity could be increased easily to 26 ton/ha. year in the short-term. This appears to be the minimum necessary for the viability of a large alcohol programme.[40] Thus the implementation of large scale cassava alcohol programme, faces serious challenges. The first concerns the high degree of risk associated with building a distillery without being assured of raw material supply. As agricultural technology is not well developed, plantation scale production is unlikely. The market price of cassava is highly unstable and subject to wide variations in price and supply. As there is no institutional framework in place for promoting cassava production, normalizing relations between farmers and distilleries, or improving productivity, it is unlikely that significant numbers of cassava distilleries will be built until regional market mechanisms are established to guarantee a stable supply of cassava at a stable price. The second problem concerns the enzymes necessary for the industrial processes (this will be discussed in Chapter 5). The third problem relates to R&D in agricultural production of cassava. The scientific knowledge of this crop is still too poor to allow for rapid gains. Only in the State of S.P. has a research programme of any significance been carried out (see Table 3.4). At the national level research activities have been mostly confined to the recently created 'Centro Nacional de Pesquisa de Mandioca e Fruticultura' (National Research Centre for Cassava and Horticulture) at Cruz das Almas (Bahia) and some research centre at the State level (not Federal). However, until quite recently most of the states did not even have a collection of existing 'native varieties'. It is estimated that there exist over 1000 different cassava varieties in Brazil, 250 of which are in S.P. alone.

Most of the genetic improvement research has been carried out in S.P.

Table 3.4 Summary of Research Carried Out/underway and Technical Assistance to Cassava in the State of Sao Paulo.

Institution	Type of Research
IAC(Agronomy Institute of Campinas)	Research on Culture Techniques -planting techniques, herbicides research, soil research. Research in Fertilizers -fertilizers use techniques Research on Genetic Improvement -new varieties developed(SRT-59-blanca de santa catarina, SRT-1099; SRT-1; SRT-454; IAC-14-18; IAC-X-352-7; IAC-7-127; IAC-24-2; IAC12-829; IAC-105-66, IAC-352-6) Disease control Seedling and rooting.
IB(Biology Institute)	Research on Anaerobic Bacterium
ITAL (Food Institute)	Research on Cassava Food Production -industrial processes of cassava-flour, conservation , utilization, protein, ethanol production, toxicity, process technology for cassava grating, tech.process for alcohol prod.
IEA (Institute of Agricultural Economics)	Research mostly concerned with cost production -cassava production cost -rural credit.
CATI(Technical Support Agency)	Research on Technological Assistance -technical information to cassava producers
	PRIORITIES RESEARCH AREAS
IB, IAC	Disease control Herbicides Culture techniques
IAC	Genetic improvement Technology research related to cassava
ITAL, IAC	Agricultural engineering research
CATI	Technical assistance

Source: Secretaria Agricultura e Abastecimento, Plano Indicativo Mandioca, Campinas, S.P., 1979, pp. 39-47.

where new improved varieties have been introduced. Of special importance are the varieties 'blanca de santa caterina', the 'IAC-mantequeira', the 'IAC-iracema' and the 'IAC-12-29'[41] as seen from Table 3.4. With such large numbers of genetic diversity, the potential for plant genetic improvement is enormous. However there exists a resistence by traditional plant genetists to adopt new methods for genetic improvement, and hence most improvements are by traditional methods - by crossing varieties. Lack of understanding of cassava further impedes rapid progress. A widely accepted view has been that a cassava distillery needs an outside supply of energy, contrary to sugarcane which is energy self-sufficient. But a study by Lorenzi and Monteiro[42] shows that Brazil produces some varieties which produce roughly equal proportions of roots and branches (see Table 3.5), that for each ton of cassava root corresponds one ton of dried matter. Therefore, theoretically at least, cassava when fully utilized to produce alcohol, does not require an external source of energy.[43] This, if proved fully practical, could have a significant impact in the future.

Modernization and productivity increases are two major challenges for the future. Time would be needed to build up institutions and train researchers to meet the needs that would arise from wider production and utilisation of cassava. In addition to research capabilities, basic production technology must be transferred to small farmers - a much more difficult task than in the case of sugarcane. Mechanization should not be seen as a danger to employment since presently cassava production uses an unnecessarily high level of labour force which is regarded as a hindering factor to the introduction of new plantations. Disease and pest control must be pursued with more vigour, particularly the '<u>xanthomus manihaties</u>', responsible for so much damage to this crop.

Despite these problems, cassava remains the best alternative to sugarcane

Table 3.5 Cassava: Productivity of Roots and Branches of Some Varieties (ton./ha).

State	Variety	Roots(t/ha)	Branches(t/ha)	Age(months)
M.G	Riqueza- Ipeaco-1	30.7	30.0	18
S.P.	IAC-Mantiqueira	37.2	27.6	23
Para	Pretinha	34.2	27.4	10
Bahia	Sutinga	19.5	22.2	14

Source: Lorenzi J.O., Monteiro D.A A Mandioca como materia prima para a produção de etanol no Brasil, Bol.Tecnico, IAC. No.67, October 1980, p.16,table 11 for alcohol production in the medium term. Industrial and agricultural technology is rapidly evolving, and once the necesseary political will/commitment has been made, the whole process could be speeded up quite remarkably.

3.5 Sorghum ('Sorghum vulgari')

Sweet sorghum is a crop which has been considered of potential relevance to the PNA due to its short growing cycle of 3-4 months, permitting multiple crops within a year, allied to its similarity to sugarcane which permits the use of basically the same industrial equipment. An additional benefit is that it can produce grain and fuel at the same time, up to 3 ton/ha. of grain in addition to its sugar-containing stalk. This crop presents, however, several serious agricultural production problems which must be resolved before it can be seriously considered as viable option for alcohol production. Current varieties are photosensitive, and produce low yields when grown during periods of the year when the length of the days is shortening. As a single crop cycle per year it is not economically viable, either plant breeding programmes must develop non-photosensitive varietes, such as the MSXS 616 being developed by Embrapa since 1976[44] (see Table 3.6), to permit two harvests a year, or sorghum must be associated with another temperate zone crop such as sugar beet. Secondly, the yield per ha. of current varieties are substantially below those of other crops in litres/ha. per harvest (25-45 ton/ha. and approximately 340 litres/ton).[45] It is estimated that average yields of 40-50 tons per harvest must be attained to make sorghum economically competitive with other crops. But basic research on cultural practices and varieties improvement is very much needed to achieve these yields yet.

A third problem relates to its rapid production cycle which complicates industrialization (1-2 weeks when sugar content of the stalk is high enough

Table 3.6 Embrapa:Genetic Improvements Obtained with Sorghum During 1977-1980(*)

Variety	Days	Total Green Matter (t./ha)	Stalks (t./ha)	leaves (t./ha)	Grain (t./ha)	Brix	Juice as % of stalk**
BR500	122	45.8	35.2	6.9	3.7	18.4	58
BR501	133	52.0	39.0	9.1	3.9	20.1	58
BR503	114	47.3	37.4	5.9	4.0	15.1	61
BR602	128	60.9	47.5	8.2	5.2	17.8	59
CMS XS616***	-	78.4	65.9	10.4	2.1	-	-

Source:
Embrapa's Centro Nacional de Pesquisa-Milho e Sorgo; Sistema Rural de Bioenergia (undated), pp.7-8,tables, 2 and 3.

Notes: *Sete Lagoas (MG), Araras, Ribeirão Preto(SP), Pelotas (MS)
** Total juice as percentage of the total amount of milled stalks.
*** Araras (SP) 1980-81.

(15%) to justify harvest). Plant genetic research must increase this period without reducing the sugar content, to diminish the loss of crop losses due to early or late maturation.

Fourthly, sorghum presents serious potential disease problems, particularly the 'Elasmospalpus liquosellus', 'Spodeptera frugiperda', 'Bioatraea spp', and the 'Schizaphis graminum'; insects and pests 'Colletotrichum graminocola' and the 'Peronosclerospero sorghi',[46] which must be fully resolved before large investments are made in distilleries using this crop as a raw material. Due to the short cycle and narrow industrialization period requiring perfect coordination between harvesting and industrial processing, plantation scale becomes necessary in standard sized 1.5×10^5 litres/day distilleries, requiring over 4 x 100 ha. of land to supply a distillery. Using two crops/year a distillery can operate for 200 days using stalks and 50 days using grain.[47] An alternative seriously being considered is the development of small-scale distilleries 2000-5000 litres/day which could allow sorghum to become a far more important crop in the future.

3.6 Forestry

Forestry is the single most important and promising energy source, particularly looking at the future. Brazil has the world's largest reserve of native forest, and as shown on Table 3.7, the potential is really enormous - some 730 million tons per year. The ecological and environmental problems caused by the destruction of forests is a well known and disturbing fact which requires no explanation here, except to say that the speed and scope of the deforestation disaster in Brazil are unprecedented in evolutionary history. At one point 88% of Brazil's territory was covered by dense forest, but by mid 1970s just over 50% remained.

A scientifically and properly managed 'energy' forest, however, should not

Table 3.7 Natural Forests in Brazil

Region	Annual Wood Potential	Observations
Amazon	520 m/tons	280 million ha.of land of which 140 million ha. can be exploited every 20 years.
Cerrados	140 m/tons	85 million ha. of land of which 50 million ha. can be used every ten years cycle.
Caatingas	50 m/tons	25 million ha. of which 15 million ha. can be exploited every five years.
Total	730 m/tons	

Source: Celestino Rodrigues E. Solução Energética, Editoras Unidas Ltda, SP. 1983, pp. 87-88.

pose serious problems because transport costs requires them to be located near the centres of consumption. This means, in most cases, plantations rather than native forests. Forestry is an important economic activity in Brazil. In 1980, 4.5% of the exports ($946 million) came from forestry derived products and this could amount to $3.3 billion by the year 2000, at 1982 prices.[48]

Reforestation began in earnest in the 1960s, stimulated by growing industrial demand (pulp, paper, export, etc.) and government incentives (Laws 4771 of 1965 and 5106 of 1966). The reforestation policy, though it was very positive, benefited mostly the Centre-South Region. In Sao Paulo this expansion was due to the paper, pulp and cellulose industry - the largest in the country; while in Minas Gerais (MG) was due to the the expansion of charcoal for the steel industry. Almost 4 million/ha. has been reforested since the 1960s, mostly of Eucalyptus and Pinus spp. Modern reforestation practices did not begin until the 1970s. In 1980 a new concept was introduced, the 'dense forest' or energy plantation which differs from the old system in that the tree growing-cycle is shorter and planting is denser. In 1978 the Programa Nacional de Pesquisa Forestal - P.N.P.F. (National Forestry Programme) was created one of whose main objectives is the study of forest energy plantation. Productivity in Brazil is among the world's highest - 50 ton/ha. of Eucalyptus graudis have been achieved - in addition to abundant land and cheap labour costs. Experiments have shown a potential productivity increase of present forests of 125% and a cost reduction of 48%. Present productivity is about 11-18 ton/ha. for Eucalyptus spp. and 14-20 for Pinus spp. The aim of the P.N.P.F. is to double such productivity.[49]

In addition to its traditional use of energy source, forestry products are becoming increasingly important as an energy source in the steel and cement industries, steam generators and thermoelectricity. In the area of liquid fuels, ethanol and methanol are actively being investigated, and important advances can be expected in the light of current research.

3.6.1 Wood Ethanol

By and large the most important programme in Brazil to produce ethanol from wood, is that of Coalbra - Coque e Alcool de Madeira S/A, formed in 1979 to investigate such possibilities. Coalbra has a domestration plant in Uberlandia (MG), operating since February 1984, so far with encouraging results, despite many initial problems. Table 3.8 illustrates the major charactristics of the originally planned plant. The plant uses only eucalyptus wood at this stage.

The process is based on acid hydrolysis technology developed in the Soviet Union and in addition to ethanol, important by-products such as methanol and furfural can be obtained. It is the only commercially available industrial process sufficiently tested over 40 years, particularly in the Soviet Union, with whom Coalbra signed an agreement for technical assistance.[50] This process has been criticized as being too costly (results so far show a 10-20% higher cost than sugarcane, very reasonable considering that it is a demonstration plant), and also for using a process unsuitable to Brazil's conditions. This is denied by Coalbra who maintain that the technology is successfully being adapted. To emphasize this point the company notes that already a number of industrial countries, e.g. West Germany, have shown interest in Coalbra's work.[51]

Coalbra has an ambitious programme for producing wood-ethanol should current research produce the expected results (some 10.7×10^9 litres by early next century at the most) and if the technical and political problems can be overcome.[52] The plan is based on the assumption that the long term oil price will increase. Wood ethanol would be obtained from planted forests in unsuitable agricultural land. It can work all year round, and the cost of the

Table 3.8 Industrial Pilot Plant of Wood-alcohol of Coalbra, Uberlandia, M.G.

INPUTS	Day	Annually
Eucalyptus wood	600 (m3)	204 000
Eucalyptus wood-chips	295 (m3)	100 000
Sulphuric acid (98%)	13.4 (t)	4 556
Lime (85%,C O)	13.1 (t)	4 454
Ammonium sulphate	5.2 (t)	1 770
Simple super sulphate	5.0 (t)	1 700
OUTPUTS		
Alcohol(hydrated)	30 (m3)	10 200 000
Furfural	1.42(t)	485
Yeast (protein)	9.35(t)	3 180
Carbonic gas	14.96(t)	5 090
Lignite (69% humidity)	100.00(t)	67 660
Lignin coke(potential)	30.00(t)	10 200

Source: Coque e Alcool da Madeira- Perspectivas da Coalbra S/A., Culturas Energeticas, 1 (3) September 1982, p.13.

Note:
m3= cubic metre
t= ton
l= litre.

raw materials would not be more that 40% of total alcohol production cost (see chapter 8) unlike sugarcane's 60-70%.[53]

Currently wood-ethanol presents a series of disadvantages which must be fully considered seriously, before embarking on a large-scale programme. Economics of scale are very large - 5×10^5 litres/day which if operating a 300+ day/year. requires an area of c. 6×10^4 hectares to maintain a constant supply of raw mterial and fuel - this depends of course on the productivity achieved. The long-cycle in forestry production of seven years from planting to first harvest, either delays the construction of industrial plants or requires the use of existing forest. Distilleries built to use such forests will creat a deficit in other sectors - i.e. building, paper, pulp, etc. particularly if the demand increases.

If the acid hydrolysis process was to be used in the short-term at least, in addition to the highly capital intensive much higher than other alternatives, it will require large amounts of imported sulphuric acid necessary for the process. It also requires large amounts of firewood, which, according to the STI/MIC estimates,[54] would lower productivity to only 1655 litres/ha./year. The cost of forestry production is higher than market prices due to hidden effects of reforestation incentives. As they have been reduced recently, and as land prices in the South and South-East have increased, the future price of wood will increase and wood production will tend to be relocated to the Centre-West, far away from alcohol demand. The commercialization of by-products such as furfural are very important for the feasibility of ethanol from wood, but currently there are not markets for large volumes of these by-products.

Considering all these factors, ethanol production from wood based on acid hydrolysis of wood is not at present an attractive alternative.[55] In the medium to long-term option may become an important source of raw material when alternative technologies are developed. Acid and enzymatic hydrolysis research, particularly microbiol enzymatic hydrolysis, is being investigated outside and inside Brazil and very significant developments can be expected in the short term which may alter the current state-of-the-art of wood-based ethanol production as will be further discussed in Section 5.8.

3.6.2 Wood Methanol

An alternative to ethanol is to produce methanol, an option that has its enthusiasts who consistently argue that it is cheaper to produce methanol than ethanol because it requires less inputs, e.g. less land, and fuel for industrialization produces larger net fuel yield., and because of Brazil's know-how and excellent conditions. Critics of wood-ethanol argue that ethanol has no future, because the USA is producing large quantities of ethanol from corn, against which wood ethanol cannot compete. These critics argue that it is better to produce methanol for industrial uses rather than fuel. The problem with methanol is its poor calorific value when used as a fuel. Brazil has already plants with capacity of 300 ton/day and the CESP has received a $26.3m. loan from the International Development Bank for research on methanol called 'Programa Metanol Combustivel'. It has already a pilot plant near Rio Claro, S.P. with capacity to produce one ton/day of methanol from 1.6 tons of wood. It has also a project for module units, each with a capacity to generate sufficient gas to synthetize 100 ton/day of methanol - methanol is produced by gasifying biomass, a process whereby vegetable raw material is tansformed into fuel gas. This gas can either be used directly as fuel or in turn used as a raw material for the synthesis of chemical products, such as methanol.[56]

CESP is also investigating the use of methanol in Otto and Diesel cycle engines, in boilers and even in locomotives. CESP notes that when methanol is free of impurities most toxic problems can be eliminated. However the cost of producing methanol is still quite high. According to some experts[57] 54500 km^2 - 0.64% of Brazil's territory could produce sufficient liquid fuels to meet Brazil's demand.

3.7 Vegetable Oils

In 1979 the ProOleo programme was set up with the aim of finding a solution to Brazil's diesel oil problems. The results have not been entirely satisfactory for political and economic reasons rather than technical ones. Firstly, there have been conflicting priorities and objectives between the Federal Government and the heavy vehicle manufacturers. Government demanded that the Diesel cycle engine should be modified to accommodate the fuel whilst manufacturers maintained that a new fuel more suitable to existing engines should be found, because of the high investment required for engine modification. Secondly, the large amount of vegetable oil required in addition to the high demand for cooking oil in Brazil and the high price in the international market, makes this option politically unattractive, in the short and medium terms. Thirdly lack of sufficient and reliable technical data and technical difficulties with vegetable oils utilization 'in natura', and problems with funds further complicated the decision-making process, and no clear policy has ever existed. In the fifth place are the vested interests within the transportation system itself, which prefers to use diesel oil. Unless there is a significant shift on diesel price policy this resistance is likely to continue because the diesel-cycle engine is very efficient and unless this efficiency can be compensated by any other forms, opposition to change will be maintained by manufacturers and users alike. Finally, a large vegetable oil programme (at least 18×10^9 litres/year. would be needed to replace diesel) would demand very large investment which the country cannot afford in the short term.

For these reasons vegetable oils cannot reasonably be expected to play a major role as diesel substitutes, except in blending with alcohols and diesel in relatively small proportions. However at local or regional levels their use may be economically justifiable at much greater scales. Indeed they may play a key role in specific circumstances. Nonetheless, a number of options are actively being pursued, which are explained in section 6.5.2.

Of all vegetable oils under study, which is quite large, two appear of particular interest - castor oil ('Brassica napus' and 'B. campestri') known also as 'mamona'; and palm oil. Babassu ('Orbinya spp') long regarded as very promising, presents many social problems because it is produced in small plots and has many traditional applications other than oil production.[58] Soy-bean oil is produced in large quantities in Brazil but it is mostly used for cooking and exports. Castor oil, on the other hand has an enormous potential for expansion in Brazil. It requires low inputs and is an excellent feedstock for fuel - already castor oil cars are running experimentally - and the chemical industry. It would not pose any serious problems to food production since it can be grown in unsuitable agricultural soils. Its potential is quite large because (i) productivity could be increased with current technology, two or three-fold from 6 ton/ha. to 12-18 ton/ha. in a short period; (ii) new varieties have been developed with very high oil content. Of particular interest is the variety 'Recinus communis L' which can produce 2100 kg/ha. in 120 days/harvest; (iii) production costs can be further reduced due to easy mechanization.[59] This plant is cultivated by small and medium size farmers and could generate, if properly managed, considerable employment.

Palm oil is also considered as a viable alternative. According to some enthusiasts of 'dende' 4.5 m/ha. (0.5% of Brazil's territory) could produce 20 m. tons of petrol equivalent of oil. There are 71.2 m/ha. of suitable land for 'dende' plantations. Cost compares favourably with petrol ($46.5 barrel p.e.)

this is against $66 barrel of diesel in Brazil.[60] Despite the considerable barriers to large-scale utilization of vegetable oils as fuels, considerable research is being undertaken and the outcome could be extremely important, far beyond Brazil's borders. Certainly vegetable oils can play a significant strategic role should the situation arise.

3.8 Sugarcane Bagasse

Finally in this chapter, one cannot fail to consider an important by-product of sugar and alcohol production: sugarcane bagasse. This is important because its commercial utilization could have a very significant impact on the economy of alcohol in Brazil; a potential scarcely used today. Indeed, until now bagasse surplus has been largely regarded as a nuisance, difficult to dispose of and therefore the philosophy of the distillery has been to be 'not too efficient' to avoid precisely this bagasse problem. However, since the creation of the ProAlcool this problem has worsened and significant efforts are being made to find alternative markets for surplus bagasse.

The bagasse surplus depends on two major variables: (i) total sugar/alcohol production; (ii) the distillery efficiency. Bagasse surpluses can be as little as 5% of total sugarcane bagasse produced and as much as 40-50% or even 70%. This is well illustrated on Table 3.9. If, i.e. 30×10^9 litres of alcohol were to be produced in the 1990s, about 7.2 m.t.p.e. of surplus bagasse would be available - just considering 30% surplus, which can be regarded as quite conservative, bearing in mind that energy/steam consumption in the distillery can be reduced dramatically - e.g. turbines for generating electricity operate at 47-55% efficiency.[61]

Table 3.9 Estimates of Sugarcane Bagasse Surplus

		Total Bagasse Surpluses				
Alcohol Production		10%	20%		30%	
(10^9)	10^6 t.	m.t.p.e.	10^6ton	m.t.p.e.	10^6ton	m.t.p.e.
10	6.6	1.1	13.2	2.2	19.8	3.3
20	10.5	1.8	21.0	3.6	31.5	5.4
30	14.4	2.4	28.4	4.9	43.2	7.2

Source: Macedo, I.C., Proceed. IIICBE. - (Third Brazilian Energy Congress), Rio de Janeiro, Oct/1984 pp.1700-7.

Many improvements can be made without much additional capital investment. For example, the poor energy efficiency of many mills/distilleries today results in a 40% deficit on the electricity supply which has to be brought from outside. This is when there are conditions to be energy self-sufficient but also to generate surplus electricity for sale,[62] which could have a major impact in the running costs of the distillery.

3.8.1 Bagasse Industrial Uses

Sugarcane bagasse can be used in addition to generating electricity/energy, in a number of other industrial uses, e.g. to produce ethanol, furfural, thermal use to substitute wood or oil, as raw material for the pulp, paper and cellulose industries, animal feed, charcoal briquettes, pellet briquettes, etc. In most cases the technology is not yet fully developed. Important advances have been made in bagasse drying, direct burning 'in nature', pressed boles, etc. But a major problem is marketing. At present there is not much demand because there is no supply. This can be explained by the traditional attitude of the sugarcane farmers, high transportation and storage costs, high subsidies to other alternative energy sources, e.g. wood, diesel, oil, etc., but principally due to a lack of marketing strategy and to the non-existence of an homogeneous technical specification for bagasse utilization. In the last few years important efforts have been made to change this situation. Some of the most promising alternatives are explained below.

Obtaining ethanol by hydrolysis saccharification is very promising, but seems to be conditioned to further improvement of the traditional Schoeller process which is the only commercially feasible method. Many enzymatic processes have been studied, but these are not yet at a commercial stage. The Scheller process can obtain c.175 litres of alcohol per ton of dried bagasse (or 250 litres/ton if pre-hydrolysis step is added) which is a low yield in addition to poor alcohol quality and high steam consumption. This requires a special yeast capable of withstanding the high toxicity; the stillage is also highly pollutant.[63]

Technically speaking the production of furfural from bagasse is not much problem. Brazil already has industrial experience in this field. The problem is cost, but since many by-products can be obtained - i.e. furfural and ethanol simultaneously, costs can be reduced. There is a demonstration pilot plant in Brazil with the following characteristics:

bagasse (50% humidity)	62 ton/day
ethanol (95%)	5000 l/day
furfural (95%)	3.4 ton/day
lignin (50% humidity)	17.5 ton/day [64]

The use of bagasse in the pulp and paper industry is well known, there exist 50 mills worldwide. But in Brazil, despite its enormous potential it is in fact declining because of (i) overcapacity of the pulp and paper industry due to world recession; (ii) the industry's large forest plantations; (iii) technical barriers, bagasse requires more sophisticated technology; (iv) transport cost and the odour caused by the bagasse. Nonetheless, this can change in the future.

There is already a market for specific uses such as hardboard, paper, packaging, newspaper printing industry. In 1977 there were 19 companies within this sector that used bagasse for cellulose, with a capacity of 60457 ton/year, 79546 ton/year/capacity in (1979), and 68647 ton/year in (1980).[65] Reduced subsidies to reforestation and growing demand for wood is expected to push the prices up, whereby sugarcane bagasse will become an economic option, at least in the medium term..

Finally the use of bagasse as animal feed looks very promising.[66] Bagasse, which can be used either directly in proportion of 2-4% of total weight mixed with other feedstocks, or processed to reduce the high content of lignin. But new processes are being developed which modify the structure of bagasse so that it can be digested by animals in higher proportions, i.e. thermal hydrolysis which increases digestibility from 23% to 69%.[67] Other alternatives consist of producing yeasts from surplus bagasse.[68] This market potential in S.P. alone is reckoned to be 1.3 m./ton/year. Another possible important market for sugarcane bagasse is the production of the additive tetrahydrofurfuryl nitrate (THFN) which will be discussed in Chapter 6.

There are many other uses, but these suffice to illustrate the potential of sugarcane bagasse, ignored in the past, but which is becoming increasingly important and whose possible impact on the economics of ethanol production cannot be ignored.

In summary we may say that whilst Brazil's agricultural sector has an enormous potential for energy crops, it faces serious challenges in respect to its low productivity. Bearing in mind that raw material constitute a very large proportion of the end product cost, increased productivity and efficiency becomes an imperative priority. Investment in agriculture has proved historically capable of great returns. Without overcoming these obstacles one cannot, realistically, expect the ProAlcool to be a serious economic alternative in the long run, considering also the present world oil situation.

Biotechnology and plant genetic engineering offer the greatest hope in improving productivity and lowering cost. In the short term one crop, sugarcane, offers the only realistic possibility for ethanol production in large scale in Brazil. This is the only area where Brazilians can offer international know-how so far. Other important crops are actively being investigated but are far behind in comparison to sugarcane. This is particularly the case with wood ethanol/methanol where new breakthroughs are likely to occur first elsewhere, rather than in Brazil, i.e. Sweden, Canada or the USA.

CHAPTER 4

ALCOHOL PRODUCTION TECHNOLOGY: THE CAPITAL GOODS SECTOR

Introduction

The industrial phase of alcohol production may be regarded as less important in economic terms than feedstock production because of its lower production costs. But for our objectives it is very important to understand the technical components of alcohol production technology. In the alcohol capital goods sector, one should distinguish two distinct historical phases. The pre-1975 period when this sector was basically a by-product of the sugar industry, characterized by conservatism and little concern for economic efficiency. The post-1975 years which represent a new challenge and when important changes began to take shape.

I shall analyze: the historical development of the alcohol equipment industry, which was the basis for the rapid expansion of this sector after the creation of the P.N.A.; market potential; plant capacity; major innovations and the foreign market potential. Finally, alcohol production technology itself can be divided into two main areas: (i) equipment technology; (ii) process technology. In this chapter I have looked at the industry in general, whilst in chapter five I assess process technology in more detail.

4.1 General and Historical Considerations

It is not uncommon to hear contradictory statements on the state-of-the-art of alcohol technology in Brazil. This may be due to a number of factors - e.g. large differences from distillery to distillery in technological level and management practices. This should not be too surprising in a country as large as Brazil. There appear to be two main bodies of opinion, in my view, with regard to the alcohol capital goods sector: (i) those who see this sector as backward and unable to come to terms rapidly enough with the new reality; (ii) those who believe that the alcohol equipment industry has become a dynamic and innovative force willing and capable of meeting the new challenge head on.

In the first case, which includes people mostly outside the industry, it is argued that the industry lacks adequate analytical instruments capable of determining what process innovations are needed, because in general old attitudes and management methods tend to prevail. Many distilleries, particularly the older ones, continue to operate without being able to optimize investment. This is because the same methods are used as ten or twenty years ago. Many distillery owners do not understand the real possibilities of improving efficiency. Thus, many small improvements which require little investment are seldom undertaken. In addition there is also little cooperation with other industries - e.g. with the alcohol consumers.

In the second case, which includes mostly the industry itself, the prevailing opinion is that the opposite holds true. They argue that Brazil has made enormous technological advances in recent years which place Brazil as a world leader of alcohol production technology - a technology that Brazil dominates completely.[1]

Both views, to a certain extent, are representative of the industry's reality because the alcohol equipment technology is a mixture of old and new, in both technology and attitudes. D'Avila summarizes well the state-of-the-art of alcohol technology:

> 'Whilst it is true that a few years ago most technology could have been regarded as traditional and obsolete, this is not any longer the case, particularly in the new distilleries. The industry is investing heavily in R&D and has already achieved significant results; and although current technology may not be fully developed or be the most suitable, it is the

most advanced technology in the market for large scale alcohol production. As for the old distilleries given the large capital investment involved, it will take time before they can update their production processes'.[2]

One must be reminded that historically the alcohol sector was a by-product of the sugarcane industry - a marginal economic activity and thus there was little regard for efficiency. Secondly, during the first few years of the ProAlcool the major concern was to maximize alcohol production in the shortest possible time and with the minimum possible investment. In such circumstances, efficiency, quality, etc. played a secondary role. Thirdly, one should recall the fact that alcohol production technology had been dormant for decades, and that there was a lack of world wide industrial experience in applying contemporary technological advances on a large scale.

In addition, the whole capital goods sector has been adversely affected by the economic recession of the early 1980s. The Brazilian capital goods industry manufactured $17.8 billion in 1982 - 12% less than in 1981 and 28% less than in 1980.[3] In 1983, 45,000 jobs were lost; and in 1984, 70% of the capacity was idle with little prospect of improvement in 1985.[4] The import policy for the past few years has made matters worse, particularly for alcohol equipment. This is because, the manufacturers argue, Brazil has imported quantities of equipment which could have been manufactured domestically. They also note that 80% of these imports do not pay any import taxes because this technology enters the country either through turn-key projects, under national priorities or through foreign financial agreements.[5]

As the Journal O Estado de Sao Paulo once put it 'this sector is suffering the political blindness of the government who accept any conditons to obtain dollars to pay for current account deficit problems. Brazil's weak position has given way to pressure without taking into account the domestic market'[6] In 1982 imports totalled $4 billion, 50% of which could have been supplied by

Brazilian domestic firms. Further, the State sector owes over $700m. to the capital goods industry. On the whole all these difficulties have put further constraints on the industry's drive to modernization.

The first incentives to the sugar and alcohol equipment industry dates back to 1875, though it was not until the introduction of Degree Law 19717 in 1931 that this sector really began to consolidate. By the late 1930s there were 172 alcohol distilleries with 5×10^6 litres/day capacity.[7] However after the second world war the production of industrial alcohol by fermentation in the chemical market was replaced by petroleum based sources, as petroleum gradually became relatively cheaper in the post-war years. Most governments, particularly in the USA and Western Europe, began to withdraw subsidies to national alcohol programmes. Only in a handful of countries, such as Brazil, production of alcohol continued, albeit on a small scale, as a by-product of the sugarcane industry.

These historical circumstances, together with the fact that insufficient priority was given to R&D in the early years of the P.N.A. are factors which the industrialists are quick to point out as a cause for the tardiness of the industry in responding to the new reality. There are of course many other factors involved - eg. lack of qualified personnel, the vested interests of the sugar mill owners and the monopolistic structure of the sugar and alcohol equipment market.[8]

The market monopoly is often blamed too for the slowness of the industry to respond to changing circumstances, particularly by the small industrialists. Bautista Vidal[9] argues that the ProAlcool created the conditions for technological innovation within the capital goods sector (see 2.5). But because this industry remained in the hands of the traditional suppliers, chiefly Dedini and Zanini, who were responsible for 80% of the market, it was obvious that these two firms would make it difficult for other companies to enter the market. At the same time there was not sufficient pressure from sugar mill and distillery owners for new and better equipment. This seems to stem from two main reasons; firstly due to the poor technological understanding of possible innovations of the mill owners and secondly due to the low level of technological dynamism characteristic of this industry.[11] With the creation of the ProAlcool, there was an increasing demand for equipment - but not necessarily for better equipment - which found a ready market; (iii) at the same time, despite this expansion, the market was not large enough to attract new firms. Most significantly perhaps, was the fact that there remained doubts about whether the ProAlcool would be halted.

The monopoly argument is disputed by Aquiar Puppo[10] who argues that there is no such market monopoly. This is because both Dedini and Zanini do not have monopoly but rather the capability to supply a whole range of products (equipment and services) which no other firms can provide. This is precisely what strengthens their position, according to Aquiar Puppo. However, this does not deny the fact that c.80% of this market is supplied by these two firms.

One should also be aware of the fact that this industry differs considerably from other industrial sectors due to the high instability of demand and price fluctuations of the international sugar markets. This according to Negri was in the past a significant stumbling block to innovative activity and a major deterrent to companies intending to enter the market.[11] It must also be recognized that one major reason why this technology did remain largely static in the past was because it served its purpose well in the Brazilian conditions - e.g. fairly efficient, low skill and capital requirements, and easy to handle.[12]

With regard to the poor energy efficiency of the alcohol equipment sector, there was plenty of cheap oil and much sugarcane bagasse available, that this should not come as a surprise. This is particularly so with bagasse whose main problem was how to dispose of it because of lack of market.

Without exception, the alcohol equipment manufacturers in Brazil began as small workshop enterprises using no new technology at all and no significant technological developments took place for decades. Dedini was quite successful in implementing technology based on simple mechanical principles. All equipment utilized was well known and developed in the industrial countries.

Dedini commenced in 1920 as a small mechanical and repair workshop for the sugar mills and alcohol plants, albeit the company was also involved in other activities. Despite a poor record of innovation, the company was able to maintain and even expand its share in this market quite successfully, either through market expansion or by taking over smaller competitors. One reason seems to have been the ability of the company to supply a whole range of spare parts (this is very important in the alcohol industry due to the high replacement ratio).[13] Dedini also took a small share of the plant's assets in exchange for its services, which served to further consolidate its market position. Zanini, the second largest traditional supplier of alcohol equipment, was set up in 1950. It operates through two subsidiaries - Zanini-Foster Wheeler (originally a joint venture with an American company) who provide technological advisory services in a large number of other industrial sectors. The second group, Zanini Equipamentos Pesados, deals with alcohol production technology.

There are a number of historical manufacturers of alcohol equipment as can be observed on Table 4.1. A large proportion of these firms have disappeared or have been taken over, many by the Dedini Group. A second feature to notice is the great concentration in Piracicaba, S.P.

Table 4.1 Historical Evolution of Sugar and Alcohol Equipment Manufacturers in Brazil.

Company	Location	Year in which it was set up
M Dedini S A-Metalúrgica	Piracicaba-SP	1920
Moplet S A-Eqip.P/Usina Açúcar e Alcool(a)	" "	1936
Codiq. S A-Constora Equip.P/Ind.Química(b)	São Paulo-SP.	1941
Codistil-Const.de Destilarias Dedini S A	Piracicaba	1943
Mausa-Metalúrgica de Aces.P/Usinas de Açúcar S A.	" "	1948
Santin S A-Indústria Metalúrgica	" "	1948
Zanini S A-Equipamentos Pesados	Sertaozinho-SP	1950
Mepia-Metalúrgica Piracicabana S A(c)	Piracicaba	1950
Jundiçào Goyacaz S A	Campos-RJ	1953
Mesoli-Metalúrgica Santa Cruz S A(d)	Piracicaba	1953
Fizanaro S A-Industrial e Comercial	" "	1954
Mario Matoni Metalúrgica Ltda.	" "	1956
Metalúrgica Conger S A	" "	1962
Tecomil-Técnica Const.Maq.Industriais Ltad	Sertaozinho	1964
Fives Lille do Nordeste (e)	Maceio-Alagoas	1967
Mefsa-Mecánica e Fundição S.Antonio Ltda	Piracicaba	1968
Metalúrgica Barbosa Ltda.	" "	1970
Cosinor-Cia Siderúrgica do Nordeste (f)	Recife-PE	1970
A.Z.F.-Semca Metalúrgica Ltda.	Piracicaba	1972
Sidel-Comercial e Industrial S A	Campos	1972

Notes:
(a) Incorporated to the Dedini Group in 1958
(b) Closed down in 1947
(c) Incorporated to the Dedini Group in 1959
(d) Closed down in 1966
(e) A subsidiary of the French company
(f) In 1970 Consinor began to manufacture equipment for the sugar and alcohol industry.

Source:
Negri B.Um Estudo de caso da Industria Nacional de Equipamentos:Analisis do Grupo Dedini (1920-1975), MA Thesis, Instituto de Filosofia e Ciencias Humanas, UNICAMP, 1977 p. 105, table 6.1

4.2 Market Potential

Thus the market of sugar and alcohol equipment has a somewhat monopolistic structure, since it is dominated by two major groups. Dedini alone was responsible for 69% of the total sales in 1983.[14] The Dedini group has benefited more than any other from ProAlcool; its share of the market increased from 54.4% in 1970 to 60.6% in 1975,[15] whilst Zanini's share declined in the same period from 18.6% and 14%. Nonetheless, in recent years a large number of companies have entered this market encouraged by the unprecedented demand caused by the ProAlcool.

Late in 1980 the journal 'Quimica e Derivados'[16] carried out an extensive market survey to find out potential suppliers of alcohol equipment technology. The survey identified those firms already supplying components to the alcohol industry, plus those firms with the technical capability to supply this market. About 70 firms were identified as being capable of supplying alcohol equipment, ranging from boilers to storage equipment, valves, steamers, etc. Many of the smaller firms complain that it is still very difficult to compete in this market despite the market changes of the past few years.

Table 4.2 lists all major alcohol equipment manufacturers. It has been compiled from different sources. A new feature which can be observed is that a large number of new companies are being set up outside the traditional areas - e.g. Piracicaba and Sertaozinho, S.P. CENAL tends to classify the alcohol equipment manufacturers by group rather than individual company. Because new companies are constantly coming to this market this table shoud be regarded as orientative.

An important new factor is the increasing number of consultancy firms offering specialized services to the alcohol industry. These include Petrobras,

Table 4.2 List of Equipment Manufactures.

Firm	Location	Observations
A. Mini and Microdistilleries		
F.Equip.Industriais Ltda	B.Horizonte	$2.4x10^3$ to $30x10^3$ litres/day plant capacity
Metalurgica Pira-Inox.	Piracicaba -SP	100 to $2.4x10^3$ litres/day Capacity
Promon	R.J	$2x10^3$ litres/day plants
Intermáketing	B.Horizonte	$1x10^3$ to $2x10^3$ lires/day
Engenharia de Calderas e Aquecedores	S.P-SP	$2.4x10^3$ litres/day
Metalurgica ITA SA	Contagem-MG	$1.2x10^3$ to $2.4x10^3$ litres day capacity
Metal Norte SA	Iparape-MG	Up to $2.4x10^3$ litres/day
R Corsini A/C	S.Carlos-SP	Up to $20x10^3$ litres/day
Fazanaro SA	Piracicaba	$10x10^3$ & $20x10^3$ litres/day
Fundaçao Tec.Idustrial	B.Horizonte	$10x10^3$ litres/day(cassava
IPT	SP	$1x10^3$ litres/day
Industrias Alambiques S. Cristovão Ltda.	Espiritu Santo	$3.6x10^3$ litres/day
CETEC	B.Horizonte	Basic engineering for sucgarcane,cassava sorghum
Máquinas Tapires SA	Barbacena.MG	Up to $5x10^3$ litres/day
Deon Hullet Ltda.	Piracicaba	$2.4x10^3$ litres/day
Interalcool	S.P.-SP	$2.5x10^3$ litres/day
A.B Equipamentos Agroindus.	P.Alegre	Up to $1x10^3$ litres/day
Alter-Energia Alternativa	S.P-SP	
Indus.Mecánica e Equip. Ltda	S.P-SP	
Metalúrgica Barbosa	Piracicaba	
Metalúrgica Miclos Ltda.	Espiritu Santo	
Steiger Industrias		
Metalúrgicas SA	Porto Alegre	
Metalúrgica Fabiano	S.Carlos-SP	
Obermaier do Brasil SA	S.P-SP	
B. Large Manufacturers*		
Conger SA Equipamentos	Piracicaba	
Metalúrgica Barbosa	Piracicaba	
Máquinas Piratininga SA	Piracicaba	
Dedini/Codistil SA	Piracicaba	
Zanini SA Equip. Pesados	Sertaozinho-SP	
Fives Lille-Filnor	Maceio-AL	
Cosinor	Cabo-PE	
Tecomil SA Equip.Industriais	Sertaozinho	
F.Coytacaz SA	Campos-RJ	
Dedini Metalúrgica	Piracicaba	

(Table 4.2 cont.)

C. Foreign Supplier/Manufacturer Groups.

Letcher&Stewart Ltda./Constractors John Brown Ltda/ Matron Consultoria e Projetos SA R.J-RJ.

Mitsubishi Corp./A.Araujo SA/Japan Gasoline Corporation/ K.F. Engineering Co. Ltd./Kyowa Hakko Kogyo Co. Ltd. R.J-RJ

SETAL/Buckau-Walter AG S.P-SP.

Speichim-Societe pou L'Equipment des Industries Chimiques France

Sork-Werkspoor Sugar B.V. Holland.

Source:

(A) Secretaria de Ciencia e Tecnología, Governo do Estado de Minas Gerais, Informe sobre Microdestilarias de Alcool, November 1982, pp.68-71.
Journal da Tarde, 11 January 1984.

(B) ABDIB- Associação Brasileira para o Desenvolvimento das Industrias de Base.

(C) CENAL. Ato No. 774/82, 25 June 1982; CENAL Circular No. 740, 29 October 1982. Ato.MMI No.662.

(*) Usually means manufacturers of large alcohol distilleries.

Promon Engenharia, Dedini, Zanini, C.T.A., Natron, Sonditecnica (Combustives Alternativos), Montreal Engenharia, among others. Thus, to a certain extent, one can safely say that this industry has evolved very rapidly in the past few years. This is also demonstrated by the ability of the Brazilian firms to bid for and win contracts in competition in the international market, an area where there is fierce competition. Until May 1984, 36 out of 38 contracts awarded for alcohol plants in Brazil covered by the World Bank financed programme, have been secured by local Brazilian firms.[17] as illustrated on Table 4.3.

The Brazilian firms may not be able to offer the latest technology, but they are able to offer standard units - even new plants are exact copies of existing distilleries using industrial standard equipment items, manufactured in bulk by relatively few experienced manufacturers. Virtually nothing is custom designed (with all the added expenses that this involves) and equipment costs are as low as can be and the same results apply to construction and installation costs.[17] Albeit Brazil's historical experience and the strong links between equipment manufacturers and the sugar mills and distilleries might be regarded as a favourable factor in securing and maintaining their market.[18]

Whether this relationship will continue to play the same role in the future remains to be seen. Despite the good performance of recent years - which has been partly due to the accumulated experience of Brazilian firms with alcohol equipment - one cannot say that Brazil enjoys a technological leadership. In fact this position is more the result of a long-term accumulated learning process, rather than a deliberate R&D strategy aimed at gaining such technological leadership. That is, most improvements have been based on empirical experience aimed at meeting a market which changed little for decades. However this is perhaps not, as it seems, the case today.

There appears to be a need for more fundamental research in this area,

Table 4.3 Awards for Brazilian Fuel Alcohol Plants Financed by the World Bank.

Bidders	No. of Awards on May 1984
A- BRAZILIAN	
Zanini	14
Dedini	13
Consorcio CCVP	8
IESA et. al.	1
B- OTHERS	
Natron/John Brown	1*
Setal et.al.	1
Technit	-
Mitsubishi	-
Speichim	-
Stock-Werkspoor	-
Total	38

Source:
Guidoboni G., European Chemical News, (12) 18 June 1984 p. 443.

* Pending on May 1984.

because as the technology becomes progressively more sophisticated, there would be a necessity for greater scientific understanding and less simple mechanical principles on which much of this technology seems to have been based. This would enable technological leadership to be gained and maintained in the future, taking advantage of Brazil's privileged position.

This is more urgent considering that the industrial countries have made greater technological progress in recent years than Brazil. This is particularly true in the case of process technology which is more sophisticated technology. The need to fully master this technology is prompted by a set of circumstances: (i) the rapid change and the nature of this market; (ii) the still relatively poor technological performance, if one considers the potential for improvement and the increased difficulties as oil prices remain steady or falling; (iii) the need to take advantage of possible demand for alcohol technology; (iv) the gradual penetration of the Brazilian domestic market by foreign firms;[19] (v) the posible saturation of the domestic market, should the expansion of the ProAlcool be checked in the meantime. In this case exports would become increasingly necessary. Plant replacement would be also a major market considering the high rate of obsolescence. However, this would demand more efficient technology because of high investment cost and the need to increase productivity.

Brazil still enjoys the advantage of a head start which places this industry in a strong position to achieve technological and scientific leadership. This will depend, however, on many factors, political, technological and world market.

4.3 Plant Capacity

Plant size is not free of controversy and argument on the pros and cons of economics of scale can be put forward. Most plant capacity in Brazil consists of relatively small size plants. The large distillery is a recent phenomenon in the country. If new plants are excluded, design engineering criteria remained within conventional lines, without any outstanding innovation. In the new ones, increased capacity has been the main characteristic, with the absence of many needed design concepts - e.g. energy balances. Whilst many old plants were built at a time when energy costs were a secondary consideration, this is no longer the case. Yet many new plants do not necessarily take fully into account the new situation.

Large scale distillery design began to be introduced from 1976 onwards. In the 1960s this capacity was around 60×10^3 litres/day, which increased to 90×10^3 litres/day in the early 1970s.[20] In the following years plant capacity standardized at 120×10^3 litres/day. More recently a few 440×10^3 litres/day distilleries have been built - unparalleled in any other country. This has been possible thanks to advances in milling, steam turbine, fermentation and distillation technologies. There have been one or two attempts to build 10^6 litres/day distilleries but so far as one can tell, without much success, rather for political and environmental reasons than for economic ones.

As already quoted in 2.3 there has been criticism against this tendency towards large scale plants even on economic grounds. Wright argues that the 330×10^3, the 30×10^3 and 5×10^3 litres/day plants are more efficient than the present standard and medium size distilleries.[21]

Plant efficiency can be influenced, however, by many other factors regardless of scale. The two main ones are (i) process technology, i.e. the extraction rate which is determined by the technology employed; (ii) the sugarcane $\underline{^o}$Brix content, which can vary dramatically, from less that 10% to over 20%. In Brazil, the average is 14-17%. This can have a dramatic impact on the final efficiency of the plant. Therefore, and contrary to other industries, raw material quality, rather than quantity is more important than plant size.

4.3.1 The Mini and Micro Distilleries [22]

As an alternative to the big industrial complex there has been a revival of interest in these small plants which were systematically neglected by the government for reasons already disclosed in Section 2.3. Indeed, according to Velho, in some states such as Parana, the boom in microdistilleries has been impressive. Supported by the local government, small producers have been encouraged to form their own cooperatives in order to run their own plants.[23]

The increasing demand for such plants is beginning to interest some of the big manufacturers, which in the past showed no interest for this market. For example, Dedini, who realizing this market potential has set up its own subsidiaries for the construction and sale of small scale plants. The entry of large firms into this market represents a significant change (see Table 4.2) and an unexpected spin off of the ProAlcool. These small units are also socially important because they require less capital and therefore there are a large number of small companies which can manufacture them. Micro and minidistilleries have been shown to be a significant factor in improving the living standard in rural areas where these small distilleries have been set up.[24]

There have been also important technological developments which further encourage the implementation of small distilleries in large scale. Productivity has been increased dramatically in recent years, from less than 40 litres of alcohol per ton of sugarcane to 55-65 litres/ton.[25] Other technical innovations already tested are the ceramic-built distillation column which consumes a fraction of the energy of a conventional distillation column. In addition to being a cheaper material, it can be supplied locally.[26] Therefore there seem to be sufficient grounds to suggest that greater priority should be given to the small plant rather than the big industrial complex.

4.4 Major Innovations in Equipment Technology

Under this heading I would like to discuss some specific cases where there have been some significant improvements. This is because a number of industrialists have confidently been predicting what they call 'a new generation of distilleries'.[27] What they mean by this is not too clear, but it involves, at least, a significant innovation or improved process. This represents a remarkably self-confident attitude. I shall discuss some of these technologies.

As previously noted, the ProAlcool has been a chief factor in stimulating change and betterment in the whole alcohol sector. The extent to which the ProAlcool has had a direct influence is not clear, except in the case of autonomous distilleries which were a direct consequence of the programme. This is illustrated on Table 4.4 which shows the steady improvement in autonomous distilleries. The table reflects principally the conditions prevailing in the Centre-South region rather than the North East. The most significant advances are in millling capacity, steam consumption, turbine technology and 30% reduction in the layout of the plant.[28]

However, the most important innovation at least introduced by Dedini, is the Biostil process. This, according to the company, represents a new revolutionary concept. Biostil was originally developed in Sweden by Alfa Laval but it is now manufactured in Brazil by Dedini under exclusive license. Data from the 120 x 10^3 litres/day pilot plant shows a very high alcohol yield, low energy consumption and large reduction in stillage. Figure 4.1 and Table 4.5 summarize the main characteristics of the Biostil process. The process works with concentrated raw materials - syrup, molasses, etc. in a continuous fermentation process in a single reactor.

There has been some criticism of Biostil because it is a high cost process.[29] Nonetheless this process does seem to represent a major

Table 4.4 Evolution of Autonomous Distilleries Efficiency. (120m3 litres/day capacity)

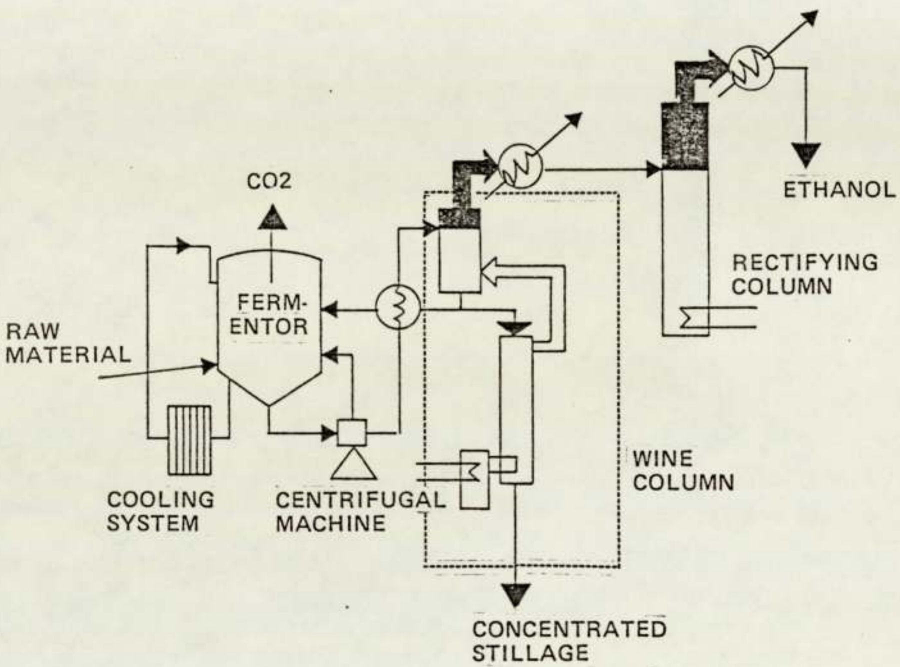
Observations	Pre-1975	1983
Milling capacity (4 press-rollers 30"x54") (tons sugarcane/day)	2 100	3 800
Press-rollers(% open cell)	c.85	c.94
Extraction efficiency of milling (% of the sugarcane juice)	92	94
Global efficiency (litres/alcohol per ton of sugarcane)	64	77
Steam consumption in the distillation step (Kg.steam per litre hydrated alcohol)	3.4	1.9
Water consumption(litre water per litre alc.)	45	40
Electricity consumption (Kwh per litre/alcohol)	0.18	0.15
Boiler steam generation(Kg bagasse p.Kg steam)	0.50	0.42
Stillage production (litres stillage per each litres of alcohol)	13**	0.7*

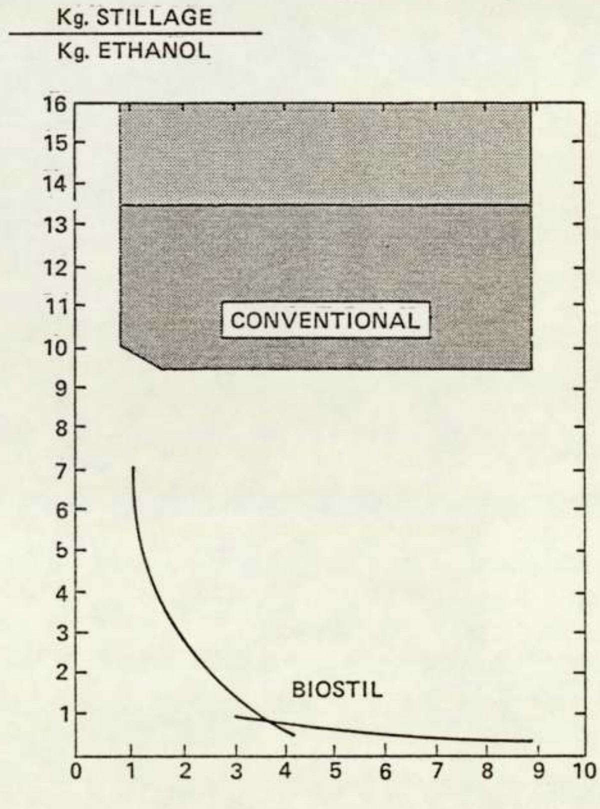
** Wine with 7% of alcohol (by volume)
* Biostill process only.

Source:

Oliveiro J L, Tecnologias Atuais da Dedini na Produçaõ de Alcool, Seminario de Tecnologí́a de Produçaõ de Alcool August 1984 (STI/MIC) p.26

Fig. 4.1 SIMPLIFIED DIAGRAM OF THE BIOSTIL PROCESS





SOURCE: CODISTIL.

Table 4.5 Summary of the Main Characteristics of the BIOSTIL Process.

- .Continuous fermentation -sterile fermentor under high osmotic preassure
- .Single fermentor
- .Pure culture
- .Raw material: concentrated feedsotck
- .Adapted yeasts: resistant to high osmotic preassure
- .Recycled yeasts
- .Alcohol recovery from CO 2
- .Coupled fermentation -distillation. Evapourated stillage. Efficiency 95.5%, depending on quality of raw material
- .Split column
- .Internal pasteurization
- .Concentrated stillage, 20 to 55 oBrix
- .Automatic process control
- .Permit adaptation to existing equipment
- .Overall efficiency 93.5%.

Source:
Dedini/Codistil

improvement and departure from the conventional engineering design concept, because of the many new parts incorporated. For example, Dedini's new Flegstill distillation process, which incorporates a significant improvement in energy consumption, does not represent a significant departure in process design.[30]

Zanini has also developed the so-called 'hybrid processes' which seem to represent an important departure from conventional design. Zanini has had a R&D programme since 1979 with financial support from the Federal Agency, FINEP, (Financiadora de Estudos e Projetos). Four main designs have been tested, aiming at the future market. Each of these new processes include what Zanini described as 'significant technical improvements'. All these models have been tested in a 20 x 10^3 litres/day pilot plant in cooperation with the University of Sao Carlos and the ESALQ in Sao Paulo. The chief characteristics are high productivity, less component parts, easier maintenance, longer life and approximately 30% cheaper than conventional processes.[31] Following is a brief description of each of these processes.

The ZANI-AT (atmospheric pressure) is based on traditional technology but 30% cheaper with longer life-cycle, simplified control, easier to operate and lower steam consumption - 3 to 3.5 kg/l. for hydrous alcohol. Operates with cane and molasses.

ZANI-PREVAC (combined vacuum pressure) has a steam consumption of 1.2-1.5 kg/l. hydrated (93.8^o) and 2.2-2.5 kg/l. for hydrous alcohol (99.3^o). In addition to low energy consumption and maintenance cost, it can operate either with sugarcane, sorghum or cassava.

The ZANI-COVIPRES main characteristic consists of its capacity to reduce the volume of stillage (1 litre stillage = 1 litre of alcohol). It is Zanini's answer to Dedini's Biostil process. It operates with both the Melle-Boinot and continuous fermentation processes. Steam consumption is 4.8-5.3 kg/l. for hydrated alcohol and fermentation time is reduced to 6-8 hours, with an efficiency of 90.3%.

The ZANI-VAC is a vacuum system capable of producing high quality alcohol because it eliminates the corrosive problems caused by poorer alcohols. It is particularly suitable for annexed distilleries whose raw material is molasses rather than the whole cane plant. Steam consumption is 2.5-4.5 kg/l. of alcohol produced, depending on the end-use product.[32]

There are other important new processes which merit attention, e.g. Cosinor's new distillation system recently introduced[33], but these examples suffice to illustrate the point that the alcohol equipment industry is attempting to modernize and to depart from the conventional path in search of new concept design. There are, of course, critics who still have doubts about this industry's capacity to fully develop this technology and they regard these new developments as 'minor innovations' without any overall real significance on alcohol production.

4.5 Foreign Market Potential

The export market for alcohol technology will be very much in function of the world's energy situation. So far the signs are that this market is expanding (see Table 4.6). But should there be a reasonable increase in world demand for such technology, Brazilian firms should be in a privileged position to compete internationally. Indeed, this could ultimately lead the Brazilian firms not only to penetrate foreign markets, but to gain, eventually, undisputed leadership. This will demand a great effort to improve existing technology - greater than seems the case so far, despite the advances of the past few years. Considering that oil prices remain steady or falling, alcohol production costs would need to be reduced very significantly.

As far as one can tell, however, Brazilian firms have been reasonably successful in their export drive if one considers the difficult economic climate, particularly in developing countries, Brazil's greatest potential market. Table 4.6 shows the main alcohol-related technology export by companies. In the first place is Dedini followed by Zanini - and geographical area. Latin America occupies first place. It is important to notice that exports of alcohol technology include the USA and West Germany. There are signs that after the slump of 1981-83, exports are beginning to pick up again as more companies are increasingly looking to the international market.

Brazilians are increasingly interested in selling alcohol too. Growing demand for unleaded gasoline, particularly in Western Europe and the USA, has created a potential export market for Brazilian alcohol. This year alone, Brazil expects to export approximately one billion litres of alcohol.[35]

Brazilian companies are also able to provide a whole range of services from consultancy, alcohol blending and fuel technology know-how, etc. on which they are trying to capitalize. There are, however, some industrialists who appear to have strong reservations besides market uncertainty. They cite two major reasons: (i) whilst currently the alcohol technology might be regarded as reasonably efficient for the Brazilian domestic market, the same is not necessarily the case for other countries (Brazilian firms manufacture standard units); (ii) lack of export credit. This is a serious difficulty because most markets are in developing countries which can buy only on long term credit. The majority of the Brazilian firms cannot offer such conditions.[39]

Overall, Brazil's potential and natural advantage, coupled with its accumulated experience, places the country in a particularly strong position to compete in alcohol-related technology in the international market, bearing in mind also that the industrial countries lack industrial experience with large-scale alcohol production technology. Yet at the same time, it is true to say that Brazil does not enjoy a technological frontier advantage, specifically

Table 4.6 Brazilian Export of Alcohol-Related Technology

Year	Firm	Country	Observations
1964	Dedini	Bolivia	$15x10^3$ litres/day plant
1970	Dedini	Paraguay	$12x10^3$ litres/day plant
1975	Dedini	Venezuela	$60x10^3$ litres/day plant
1977	Dedini	Bolivia	$30x10^3$ litres/day plant
1978	Dedini	Costa Rica	$12x10^3$ litres/day 2 plants
1979	Dedini	Paraguay	$12x10^3$ litres/day plant
1984	Dedini	Nicaragua	A turn-key alcohol plant
1984	Dedini	Bolivia	Alcohol equipment
1975	Zanini	W.Germany	Joint-venture with Zahnraedfab
1978	Zanini	Panama	Set up a company to market alcohol technology worldwide
1979	Zanini	U S A	Agreement with Foster -Wheeler to sell alcohol techonology
1984	Zanini	Argentina	Alcohol technology
1984	Zanini	Ivory Cost	Alcohol technology
1984/5	Zanini	Pakistan	Alcohol distillery
1976	Conger	Peru	Pilot plant
1977	Conger	Venezuela	$7.5x10^3$ litres/day plant
1979	Conger	Kenya	$60x10^3$ litres/day turn-key
1979	Petrobras	Costa Rica	Gasohol know-how
1985	Confab	U S A	Alcohol technology

Note:

Other companies such as Fives Lille, Piratinga and Tecomil heve also been exporting alcohol technology.

Source: This information has been compiled mostly from companies information.

in process-technology - a precondition to maintain a leadership position. There are already signs that Brazil may fail to fully capitalize this opportunity in the short and medium terms because of lack of financial export credit and insufficient attention to R&D, particularly basic research. In the next few years research should receive more attention so that this industry can maintain its leadership. As D'Avila puts it: 'The ProAlcool constitutes the best testing ground for new alcohol technology developments in the world. It is up the the Brazilians to take advantage of their opportunities'.[37]

CHAPTER 5

ALCOHOL PRODUCTION TECHNOLOGY: PROCESS TECHNOLOGY

Introduction

A close analysis of the process-technology of the alcohol industry seems to suggest that this is an area where many Brazilian firms are lagging behind their counterparts of the industrial countries. This is partly due to two main reasons, (i) Brazil's weakness on fundamental research (e.g. physiology of micro-organisms, which limit the development of new strains; or lack of new and efficient fermentors which requires advanced designs; (ii) the state-of-the-art of fermentation technology in the industrial countries is advanced compared to that of Brazil. Even though the industrial countries lack the experience of alcohol production on the scale of Brazil.

I will examine the most important fermentation-based industrial processes, for alcohol production in Brazil - extraction, fermentation, distillation, stillage recovery, cassava, and cellulosic technologies. I shall make some international comparisons so as to form an overall picture of the state-of-the-art of this technology in Brazil. Cellulosic technology is also examined because of the emphasis on feedstock diversification and the potential and interest that exist in Brazil.

5.1 Advances in Process Technology

As discussed in chapter 1, in recent years the number of R&D and commercialization projects, in all phases of energy from biomass and waste, has grown at a phenomenal rate. Many of these research projects remain at laboratory scale test plants, since most of these projects commenced in the late 1970s. Numerous advances have, nonetheless, been made, particularly in extraction, milling, fermentation, distillation, etc.

In the specific case of Brazil, significant advances have been made on almost all fronts, although in many cases it consists of minor improvements. Fermentation, in almost all cases, is still batch fermentation with yeast recycling, with distillation performed in stainless steel columns under lower pressure. Continuous fermentation is just beginning to be introduced. The same can be said of automation, particularly in the fermentation and distillation steps.

5.2 Extraction Technology

Extraction technology has received considerable attention in most sugarcane growing countries, particularly in South Africa. In Brazil a significant innovation activity has taken place thanks to the ProAlcool and more specifically, due to the introduction of South African technology by Copersucar. Extraction techniques have advanced rapidly, e.g. milling automation . Milling is the oldest and most expensive technology used in Brazil, particularly the steam-powered boiler mill, pioneered in Sao Paulo. Extraction efficiency has increased significantly in the past few years (see table 5.2), however a 4% loss of all fermentable sugars is not uncommon. The traditional preparation of cane generally employed two knife sets, now being improved by higher speed and power on knives motion, use of shredders, Doney feeding; presser roll, feeder roll and compound inhibition.

New methods are being tested, such as the use of the diffuser, which has been recently introduced in Brazil. According to its advocates the diffuser can achieve an efficiency of 96-97% of theoretical, is about 50% cheaper to operate, consumes over 26% less energy and because it is much cleaner than the milling system, it is much easier to prevent juice infection. However, the diffuser has been tried before and has failed precisely because of infection problems.[1] It is a well known system in many sugarcane growing countries. In Brazil, Embrapa has a programme to test the feasibility of the diffuser as mentioned above. If this research proves satisfactory, it could have an important effect in reducing milling costs. This is particularly important to the small units whose major drawback has been the high cost of the milling process.

Although the diffuser is successfully used outside Brazil, particularly in South Africa, there are difficulties with this new technology because sugarcane varieties in Brazil are more fibrous than those of South Africa and more difficult to crush and open all cells. Milling on the other hand offers many advantages and operates well under Brazilian conditions. For example, milling can be adjusted to operate according to demand and its peformance can still be significantly improved. This is an area, generally speaking, where Brazilians can hardly offer anything new.

In the area of juice treatment, there have been quite serious problems in the past, when infections were frequent. However, in the past few years there has been an improvement in juice treatment. For example, the introduction of pre-concentration stages have led to increases of up to 18% in the total sugar content of the mush, which produces 'beer' with 9^{o}GL of alcohol compared with 6-7^{o}GL prior to 1975.[2] There are various models of mash preparation. The conventional one consists of juice filtration followed by its pasteurization. This allows higher ethanol yields because there are practically no sugar losses, and the nutrigent elements for the yeast are maintained in the brotch to be fermented. Another juice treatment consists of a concentration of 30-40% juice value for obtaining a syrup with 60-65% of soluble solids. Cane juice clarification is also heated in order to eliminate impurities. In summary, once could argue that juice treatment has not received the attention it requires, although now far greater attention is being paid to this problem.[3]

5.3 Fermentation Technology

Thousands of years ago, people learned to produce wine, cheese and bread through fermentation. Fermentation began as a 'science' in 1857 when Louis Pasteur discovered that it was the result of action of specific micro-organisms. Fermentation as an 'industry' began early in the twentieth century, with the production of microbiol enzymes, organic acids and yeasts. The commercial use of fermentation techniques developed significantly during the first 30 years of this century. By 1925, 85% of all industrial solvents used in the USA were being produced by fermentation. But after the mid 1940s many chemical production processes that were based on fermentation were replaced by synthetic processes based on crude oil. Fermentation continued to be used by the pharmaceutical industry in the 1950s. In the 1960s due to cheap chemical feedstocks, there was a further move from fermentation.[4] Only recently has fermentation become economically important once again.

Fermentation technology has received considerable attention in the past decade and a significant work is currently in progress on the development of suitable fermentation conditions and on organisms selection. The production of carboxylic acids, alcohols, glycols and ketones from biomass and waste are good examples. But the greater efforts are being devoted to improve ethanol processes. Much of the current research on fermentation ethanol has been concentrated on improving cellulose hydrolysis, increasing ethanol yields, reducing fermentation time and achieving higher net energy production efficiency.[5] Table 5.1 summarizes the main alternative fermentation systems under investigation. As can be seen the current commerical processes have a very low productivity in terms of gramme of ethanol per litre. The alternative

Table 5.1 Industrial Productivity of Alternative Fermentation Systems Utilizing Yeasts.

System	Productivity (g. ethanol/1/h)	TA(a)
Continuous,differential pressure recycle (flash-ferm)	80	LS(b)
Continuous,vacuum, recycle	80	LS
Continuous,vacuum	40	LS
Continuous, recycle	40	D(c)
Rotor fermentor	36	LS
Batch,recycle	15	C(d)
Continuous, multi-stage	12	C
Continuous	5	C
Batch	2	C

Notes:

TA(a)= Technology available; LS(b)=lab stage; D(c)=Commercial

Source:

Kosaric N. et.al.Ethanol Fermentation, Biotechnology (H.Dellweg Ed.),Verlag Chemie, Basel (1983), Vol.3, Chapter 3a. p. 272, table 7.

continuous fermentation processes under development leave far greater productivity, although these processes are more expensive and difficult to operate.

Current approaches also include the use of bacteria rather than yeasts (see 5.4.2) simultaneous saccharification, and fermentation of low grade cellulosics with enzymes and yeasts; thermophylic anaerobes for one step hydrolysis; packed columns containing live immobilized yeast cells or both enzymes and yeast cells, etc.[6]

The batch fermentation process continues to be the most widely used process. Batch processes were developed over a hundred years ago by the beverage industry. It is based on the simple batch fermentation of carbohydrate feedstocks. The efficiency is about 90-95% of theoretical with a final ethanol concentration of 10-16 w/v; -cell-recycle has also been used in many cases in an effort to increase fermentor productivity and retaining the simplicity of the batch process. This technique does not increase the efficiency of sugar to ethanol conversion; however the time required for the fermentation to run to completion is reduced by as much as 60-70% over traditional batch methods.[7]

Continuous fermentation on the other hand, eliminates much of the unproductive 'down-time' associated with batch culture. Cell recycling is used to overcome low cell density limitation with much of the microorganisms returned to the fermentor; an extremely high cell concentration may be maintained. Complexity arises, however, due to the requirement of some separation device in the process.

Ethanol is produced at low concentration because it is toxic to its producer organism or yeast. This toxicity represents a biological limit to the economic efficiency of ethanol production by fermentation. Therefore any comparatively small increase in product concentration would result in a considerable saving in fermenation cost. New industrial fermentation, however, is being designed, capable to strip out ethanol produced by yeast fermentation before it can poison the cells.[8]

Thanks to new developments in biotechnology and genetic engineering, fermentation technology is expected to advance rapidly. Advances on molecular genetic and particularly of DNA sequencing, clinical DNA synthesis, DNA enzymology and cloning, offer novel opportunities for the fermentation industry. Among the new developments expected are: improved fermentation processes for complete utilization of both hexoses and pertoses, simultaneous hydrolysis and fermentation of cellulosis, low cost multistage acid hydrolysis processes for cellulosics; distillation separation of ethanol-water mixture via extraction; absorption-desorption on solids; and selective membrane permeation and bioreactors, in which resident-times are reduced from days to minutes; increased ethanol tolerance; improved temperature stability of micro-organisms and/or their enzymes, among others.[9]
What I am arguing is that this is an area of tremendous R&D activity, particularly in industrial countries, which will make more difficult for Brazilian firms to compete in the medium term. One reason is Brazil's weak position on fundamental research (e.g. microbiology, enzymology, etc.). One cannot expect to develop an advanced fermentation technology without a strong base on basic related sciences.

5.4 Fermentation Processes in Brazil

Fermentation in the Brazilian alcohol industry is carried out almost exclusively backwise with little or no feedstock preparation. To increase the efficiency of the fermentation step, the Melle-Boinot process is utilized. This involves centrifugal recuperation of the live yeast from the fermentor, normally 10-15% by volume of total and reinnoculation to other fermenters.

Instrumentation is generally limited to temperature control and that required by inventory purposes.

Fermentation tanks are built in carbon steel and it can be 'upside-open' or closed tanks, although there is a tendency now to use closed tanks to minimize alcohol losses.[10] There are many small improvements which are needed and that could be made without much investment cost - the total capital cost of the fermentation step represents 2-3.5% of the distillery. Fermentation technology has been developed elsewhere and then adapted to Brazilian conditions. The actual efficiency of fermentation is hardly known in Brazil.

There are two particular areas however, which require urgent attention: (i) fermentation temperature control which should be maintained at 32^{o} centigrade, but reaches usually 38-40^{o} centigrade because of the low efficiency of the traditional internal cooling system generally used in Brazilian fermentation tanks; (ii) microbiological control of fermentation which is still done without effective control, commonly resulting in contamination or infection by foreign yeast or bacteria.

Despite these problems many improvements have been made in fermentation technology. Among these improvements are better temperature control, greater alcohol concentration, improved alcohol quality, greater alcohol tolerance.[11] But at the same time experts have pointed out that the fermentation efficiency could be increased. According to Almeida Lima if all fermentation processes were to be optimized, the production of alcohol could be increased by 30% without any additional capacity or equipment being added.[12] Vianna Amorin also argued that if by 1985 all Brazilian distillieries were to operate with a fermentation efficiency of 86-88% of the theoretical maximum, an additional one billion litres of alcohol could be produced without any additional sugarcane production.[13]

Table 5.2 illustrates the overall industrial efficiency of alcohol distilleries for extraction, fermentation, distillation and fermentable sugars. The first thing to notice is the wide variation of estimates. It is highly probable that these estimates reflect more the Centre-South region than the Northeast. Fermentation times vary considerably - from over 24 hours to less than six hours.[14]. In some cases, fermentation time has been reduced dramatically. The only limiting factor to shorten further this time has been the problem caused by foam in the fermentation process; because both the mechanical foam-breakers and chemical antifoam agents can be expensive. A new and cheaper anti-foam is being developed, however, which looks promising.[15]

Despite the improvements on fermentation technology, at national level however, fermentation efficiency is still poor. The problem is, as Vianna Amorin commented, that most distillery owners believe that there are no problems with fermentation.[16] Studies by Copersucar also demonstrate that fermentation technology has not improved as much as one might expect, certainly less that it should, and that there exists great scope for improvement. Fermentation efficiency within the Copersucar group was 82.9% in 1977/78 and 86.3% in 1982/83; fermentation time was reduced from c.14.5 hours to 13.22 hours respectively.[17] This tends to confirm that significant improvements have been made in very special cases only.

A further example is continuous fermentation. In 1983/84 harvest only eight distilleries, all located in SP, were operating continuous fermentation processes, producing 4×10^8 litres of alcohol per harvest.[17b] Higher investment costs, risk of infection and the need for highly qualified personnel are reasons frequently mentioned by distillery owners and equipment manufacturers, as the main obstacles for the introduction of continous fermentation processes. In addition one can detect a very conservative

Table 5.2 Average Industrial Efficiency of Distilleries.

Percentage	Pre-1975	Currently	Short-term forecast
Extraction(a)	-	91(1981)	94-97
Extraction(b)	88	94	96
Fermentation(a)	-	91(1981)	94-97
Fermentation(b)	78	90	92
Fermentation(c)	80	89(closed tanks)	-
Continuous Ferm(c)	-	91(93% Biostil)	-
Distillation(a)	-	94(1981)	97-98
Distillation(b)	95	97	98.5
Distillation(c)	98.5	98.5	>99(Biostil)
Fermentable sugars (Kg per ton cane(a)	-	140(1981	160
Litres alcohol per ton of sugar(a)	64.7	65.5(1983)	70-75
Overall Efficiency(b)	63*	80	85

Notes: * 70-75 in São Paulo.

Sources:

(a) Instituto de Administração, University of São Paulo, Produção e Analisis Tecnológico do Alcool, October 1981 p.35, table 12.
(b) SOPRAL Informativo 2 (26) December 1984
(c) Dedini, I Seminario de Tecnologia Industrial de Produção de Alcool, August 1984.

attitude of the industry and the relatively low priority given to new fermentation technology. One reason being that most distillery owners regard the extra gained production not worth the extra investment cost.

However, this is not to deny that new processes are not being investigated as can be seen on Table 5.3 which summarizes the main fermentation processes under investigation. A number of companies and university institutions are actively researching new continuous fermentation processes. The table does not represent all research projects now underway in Brazil but it is a good indication of such activity. An additional development in fermentation technology is that for the first time the equipment manufacturers appear to be taking seriusly new fermentor design. This was an area which they paid scant attention to in the past and for which the industry has been often criticized.

5.4.1 Research on Microorganisms/Yeasts

The desired characteristics of an industrial ethanol process are highly dependent upon the choice of organisms used in the fermentation. Microorganisms and yeasts are an important research area today, specifically aimed at developing new strains for ethanol production. Already a multitude of strain variations have been produced, as noted bove. The Brazilians are also greatly concerned with improving and developing new microorganisms and yeasts, particularly since the creation of PRONAB. The main concern is with greater tolerance to ethanol concentration, selection of new yeasts, more tolerance to temperature, etc.

Table 5.3 Main Research on Continuous Fermentation in Brazil.

Company	TA(a)	Observations
CEPED	L	Vacuum fermentation, final stages of development.Capacity 1000 litres/day. High yeast concentration (50 g/l). Low stillage production.Fermentation time 3-4 hours.
INTER-UHDE (Ho ECHST-UHDE)	PP	Cell-recycle; closed tanks.Productivity 8.5% (by volume).Capacity 1500 litres/day Fermentation time 4 hours.Productivity: 45-47 Kg ethanol per 100 Kg of glucose. Effic. 92%. Investment cost:30% lower than batch.
SCIENTIA	PP	Immobilized cell.High yeast concentration. Capacity 3000 litres/day;low volume of stillage.Mechanically agitated. Fermentation time: 3-4 hours. Lower investment cost than batch.
COPERSUCAR		Cell recycle. High yeast concentration. Overall efficiency: 96%. Tested in a 120 m3/day distillery. (This process is an adaptation of the batch process to continuous fermentation).
IPT	L	High yeast concentration (50 g/l). Mechanically agitated. Capacity: 5000 litres/day. Reduced fermentation time.
UFRJ	L	Tower fermentor. High yeast concentration Fermentation time: 6 hours.
ZANINI		This company is carrying out research on different types of continuous fermentation.
CODISTIL		As Zanini, has also began research on continuous fermetation processes and new fermentor design.

Source:
Compiled from Correia Aires E J., Santos Neto R G. Fermentação Continua-Estágio Atual, I Congreso Brasileiro de Alcoolquímica, São Paulo, 1981.

Notes: L=Laboratory satage
PP=Pilot plant

Although this is an area where genetic engineering techniques are expected to play an increasing role in resolving many of today's ethanol production problems, in the case of Brazil there are doubts whether the country has the capability to use these novel techniques, at least in the short-term, as mentioned above. In spite of these doubts, research on new yeasts and microorganisms is growing steadily in many universities and research centres, and already important results have been obtained.

The ESALQ, has been researching new yeasts for a number of years. Of special significance is the IZ1904 yeast which had achieved a maximum alcohol content of 8.5% (by volume) at 20°C within 9.5 hours of fermentation and a yield of 90.01 g/l.[18] Hybridization of yeasts have also been successfully carried out at the ESALQ. Of particular significance is the M300A yeast, already used in the industrial production of alcohol quite successfully too, with an overall efficiency of c.90%. The genetically improved '<u>Aspergillus spp</u>' has also achieved an efficiency of 90% of starch conversion.[19] Yeast species used in ethanol fermentation are eumycet, unicellular fungi which exhibit a number of different ways for growth and multiplication. Yeasts are capable of utilizing a variety of substrates depending upon the species in question. In general these organisms are capable of growing and efficiently fermenting ethanol at pH between 3.5 to 6.0 and temperatures from 28-35°C.[20] But yeasts are highly susceptible to ethanol inhibition; concentration of 1 to 2% (w/v) are sufficient to retard microbiol growth and at 10% (w/v) alcohol, the growth rate of the organism is nearly halted. Hence the importance of finding new organisms capable of greater tolerance to alcohol and temperatures. Table 5.4 shows some ethanol from carbohydrate production microorganisms. It is based upon data provided by Vergara of Promon (Rio de Janeiro). Contrary to what may be deduced from the table, little attention has historically been

Table 5.4 Ethanol from Carbohydrates Production Microorganisms.

Microorganism	Substrate	Main End-Product.
Saccharomyces cervisiae	Hexoses	Ethanol, CO_2
Zimomonas mobilis	Hexoses	Ethanol, CO_2
Ruminococos albus	Cellulose/ hemicellulose	Ethanol, CO_2 acetic acid
Clostridium thermocellum	Cellulose/ simple sugars	Ethanol, CO_2, acetic acid, lactic acid.
Clostridium thermosaccha-rolyticum	Hemicellulose Pentoses	Ethanol CO_2, acetic acid, lactic acid
Bacillus macerans	Starch/sugars	Ethanol, CO_2, acetone.
E. amylovora	Sugars	Ethonol , CO_2, lactic acid.
L. mesentoroides	Pentoses	Ethanol, CO_2, lactic acid.
S. ventriculi	Hexoses	Ethanol, CO_2, acids.
T. reesei	Cellulose	Glucose.

Source:

Vergara W., Improving the Scenario for Ethanol Production. The New Ethanol Producers. Proceed. IV International Symp. of Alcohol Fuels Technology, Guarujá, São Paulo, 5-8 October 1980, 144, table 3.

dedicated to 'Saccharomyces spp' substitutes for large scale alcohol production. 'Z. mobilis' has been judged as a potentially important alcohol producer, and the 'Zimomonas'also offers comparative advantages; and the 'B. macerans' which represents microorganisms with amylase activity and ethanol production. These microorganisms may be the focus of much attention and interest in Brazil for starchy substrates.[21], such as cassava.

5.4.2 Yeast v. Bacterial

During the last few years a variety of bacteria have become the focus of biotechnological interest as ethanol producers, in addition to the classical yeasts. Numerous bacterial are able to produce ethanol under both aerobic and anaerobic conditions. Many of these organisms, however, generate multiple end-products in addition to ethyl alcohol - i.e. butanol, isopropylalcohol. But being bacteria cells more primitive than yeast cells, it would be easier to obtain strains able to withstand higher carbohydrate and alcohol concentrations which would diminish the cost of production by allowing smaller reactors and a more efficient distillation process.[22] Because ethanol production requires microorganisms which are adapted to the specific technical conditions of the fermentation industry, above all temperature and ethanol tolerance and the ability to use a broad range of substrates - some bacteria seem to be superior to the yeasts, particularly 'Thermophilic and Mesophilic' bacteria.[23] The studies by Vergara demonstrate that there exist ample attractive opportunities for utilization of 'non-traditional' microorganisms in large-scale ethanol production. Laboratory and pilot plant data forecast a 21% reduction in continuous fermentation cost (excluding raw materials) from current Brazilian conditions when 'Z. mobilis' is used instead of 'S. Cervisiae'. Likewise a 30% decrease in fixed investment is associated with a continuous fermentation of 15 x 10^3 litres/day capacity operating with 'Z. mobilis.[24]

5.5 Distillation Technology

Distillation is the traditional method for alcohol concentration from dilute alcohol-water solutions. The separation of alcohol and water by distillation is make possible by the difference in boiling points of ethanol (78.5°C) and water (100°C). The main advantages of distillation process for ethanol concentration are the absence of a requirement for other substances and the simplicity of standard technology. The drawbacks are a significant consumption of energy, mainly in the form of steam and formation of azeotrope under normal conditions.

Thus, distillation being a high energy consumption process, a great deal of effort has been expended over the years designing and engineering economic distillation of plants. Investigation is currently focussed on the development of alterntive separation processes for distillation. Table 5.5 shows projected energy requirement for novel ethanol-water separation processes. Except for vacuum distillation, all other processes consume less energy than conventional distillation. All these major developments on ditillation technology are taking place mostly in industrial countries.

Distillation technology in Brazil however, has changed very little in recent years, and it is just now really beng innovated with an energy, conservation concern, investment reduction and stillage recycling very much in mind. Usually distillation columns are too big for their planned production[25] which reflects little concern for energy consumption. Distillation is produced in columns with bubble captrays, low pressurization, heated with exhaust steam from milling driving turbines or from electric power generator turbines which have a relative pressure of 1.5-2.5 kg/m^2. Control is manual, usually from a single control panel equipped with temperature indicators, rotometers and hand-operated.

Table 5.5 Projected Energy Requirements for Alternative Ethanol-Water Separation Processes.

Separation type	Ethanol(%) Initial	Final	Process	Energy Required(kJ/l)
Complete	10	100	Conventional "dual"Distil.	7650
Complete	10	100	Extraction with carbon dioxide	2200-2800
Complete	10	100	Solvent extraction	(a)1000
Complete	10	100	Vacuum distillation	(b)10000
To azeotrope	10	95	Conventional distillation	5000
To azeotrope	10	95	Vapour recompression distillation	(a)1800
To azeotrope	10	95	"Multi-effect" vacuum distillation	(e)2000
Azeotropic	95	100	Conventional azeotropic distillation	2600
Azeotropic	95	100	Dehydration via adsorption	(d)330
Azeotropic	95	100	Low-temperature blending with gasoline	(e)840
Azeotropic	95	100	Molecular sieve	1300-1750
Other	5	10	Reverse osmosis	140

Notes:

(a) Figure given in thermal energy required to provide mechanical energy from the process.
(b) Single column distillation.
(c) For three column distillation.
(d) For drying with CaO; energy requirements using fermetable grains would be considerably less.
(e) Results directly in production of gasohol.

Source:

Kosaric N. et.al. Ethanol Fermentation; Biotechnology, (H.Dellweg Editor) Balse, 1983, Vol. 3,Chapter 3a, p. 537, table 39.

Among the new improvements one may cite, are indirect heating utilization (by heat exchangers) in stripping columns, to enable the re-use of condensed water for boiler feeding and reduced stillage volume; pressurized and vacuum columns; process instrumentation and automation, and less steam consumption.[26] Despite these improvements (see also Table 5.2 and Section 4.4) distillation technology in Brazil displays little know-how, and most of these improvements are based on foreign know-how. This technology remains, in the main, traditional and too energy intensive. New designs need to be introduced, more flexible to allow for the production of different types of alcohols; reduce water consumption and by-products and capable of operating with low-steam pressure, among other considerations.

5.6 Stillage Technology

A major criticism and preoccupation with the ProAlcool is the problem of the disposal of the large volumes of high biological oxygen demand (BOD) stillage or spent mash. Stillage is produced at the rate of 12-14 litres per each litre of alcohol, an estimated $14x10^9$ litres in the 1985/86 harvest alone. However a number of new technologies and options are under consideration which could assist in tackling this problem quite considerably, which I shall examine.[27]

Currently a good proportion of the stillage is being confined in temporary and unsuitable lagoons as a means of avoiding water pollution. Although there are already some technologies which can reduce the volume of stillage quite considerably, the problem is far from being solved as yet. The only commercial process in operation is Dedini's Biostil, although other processes are in a development stage and old ones are being improved. Some of these technologies could be incorporated with existing distilleries without much difficulty, depending on the layout of the plant. According to a STI/MIC study most of these processes can be economically viable in the short-term. The 25 to 30 ^{o}Brix concentration processes represent the best alternative, because they can reduce cost considerably. If this concentrated stillage is used as a fertilizer, as much as 75% of the cost could be saved - e.g. a 12 x 10^4 litres/day distillery could save over 12 x 10^4 dollars per year (at 1984 prices). From 30 to 60 ^{o}Brix, however, the gain to the distillery is comparatively small.[28]

In addition to the new processes mentioned in 4.4 above, CONGER has also developed a process which uses surplus energy from distillation to concentrate stillage up to 25-35 ^{o}Brix, with a steam consumption of 1.5kg.cm^2; and produces one litre of alcohol per 1.15 litres of stillage.[29] Dyna Engenharia S/A also claims to have developed a cheap process which reduces by 75-80% the BOD level of stillage. The process consists in treating the fermented broth prior to distillation for further purification. After the distillation step, the broth is treated again by adding salt, iron and aluminium to eliminate the harmful effects of the stillage.[30] Whether these processes can become a commercial reality in the short term remains to be seen. Nonetheless no one could deny the growing concern to tackle the stillage problem, which is part of a much wider problem. For example, a parameter that most influences the stillage/alcohol volumetric ratio is the beer alcohol content, which is also a function of the type of alcohol distillation system employed. The higher the alcohol concentration in the fermentation mash, the lower the volume of stillage and hence improved fermentation processes have a major role to play. For example one litre of alcohol at 7^{o} GL concentration would produce 14.8 litres/stillage but at 11^{o} concentration would produce 9.4 litres of stillage only.[31]

Stillage is, on the other hand, a potential source of revenue for the distillery if a commercial use can be found - i.e. as a fertilizer. The 140 x

10^9 litres of stillage has been estimated to be the equivalent of 49×10^3 tons of N. 30×10^3 tons of phosphorous (P_2O_5) and 3×10^5 of potassium (K_2O). This in turn can produce 2.3×10^4 tons of sulphate of ammonia, 1.5×10^3 of simple superphosphate; and 42×10^4 tons of potassium chloride.[32]

Table 5.6 lists the mean composition of the 'in natura' stillage produced in Brazil. In all types considered, the organic fraction represents about 80% of the total solids content. They are mainly composed of proteins, dead yeast cells, residual sugars and ethyl alcohol. It is worth remembering that stillage composition depends on many factors and hence it tends to vary. The most common use of stillage is its use 'in natura' as fertilizer, because its richness in nutriments can restore soil fertility. This practice is by no means new in Brazil, but goes back to the 1930s. Stillage has been used in sugarcane plantations but also for other crops such as beans, cotton and sorghum. Increased yields of 15, 7.4 and 2.4 times have been obtained for beans, cotton and corn respectively.[33] However the use presents its own problems too. Firstly it is difficult to establish fixed amounts of stillage to be used without a physical and chemical analysis of both soil and stillage; secondly, although stillage fertilizer can be applied with a modest investment, e.g. by aspersion irrigation, using hydraulic pumps and stainless steel pipes, this is not always possible.[34]

Anaerobic fermentation and biogas recovery are also very promising alternatives. This would have the following advantes: (i) reduction of BOD by 70-90%, in addition to producing biogas at a rate of 0.3-0.5 m^3 per kg. of BOD.[35]; (ii) a 13-40% improvement of the energy balance of the distillery; (iii) production of SCP (single cell protein) is promising too, because several microorganisms, yeasts, bacteria, fungi and algae can be grown on the spent mash from different sources of raw materials, particularly the '<u>Candida spp</u>' and '<u>Aspergillus oryzae</u>'.[36]

Table 5.6 Mean Composition of "in natura" Stillage Produced in the Brazilian Alcohol Production. (g/l).

Parameter	Type of Stillage			
	Molasses	Cane-juice	Mixed	Cassava
Total solids	81.5	23.7	52.7	22.5
Volatile	60.0	20.0	40.0	20.0
Fixed solids	21.5	3.7	12.7	2.5
Carbon (a)	18.2	6.1	12.1	6.1
Reducing substances	9.5	7.9	8.3	6.8
Crude protein(b)	7.5	1.9	4.4	2.5
Potassium	7.8	1.2	4.6	1.1
Sulphur	6.4	0.6	3.7	0.1
Calcium	3.6	0.7	1.7	0.1
Chlorine	3.0	1.0	2.0	0.1
Nitrogen	1.2	0.3	0.7	0.4
Magnesium	1.0	0.2	0.7	0.1
Phosphorus	0.2	0.01	0.1	0.2
BOD	25.0	16.4	19.8	18.9
COD	65.0	33.0	45.0	23.4
Acidity (c)	4.5	4.5	4.5	4.5

Notes:

(a) Carbon content= Organic solid content plus 3.3
(b) Crude protein=Nitrogen content x 6.25
(c) Expressed in pH units.
(Since the mean composition of stillage "in natura" varies, this table should be seen as orientative).

Source:

Costa Ribeiro C, Castello Branco J R. Centro de Tecnologia Promon (Rio de Janeiro).

The high volume of highly polluting waste generated by the distilleries should not constitute a serious constraint, since there are several existing procedures of treatment and utilization with other improved methods in sight. The still poor definition of measurement intended for stillage recovery can be attributed mainly to the fact that stillage has always been regarded as a waste. But as the consciousness of the environment grows, together with an increasing awareness of the economic value of the 'vinhoto' and a tougher law enforcement, the problem could be reduced.

At the same time, this is an area where Brazilian firms are acquiring much technical know-how and experience, which can be of extreme importance for other nations intending to follow this biomass path.

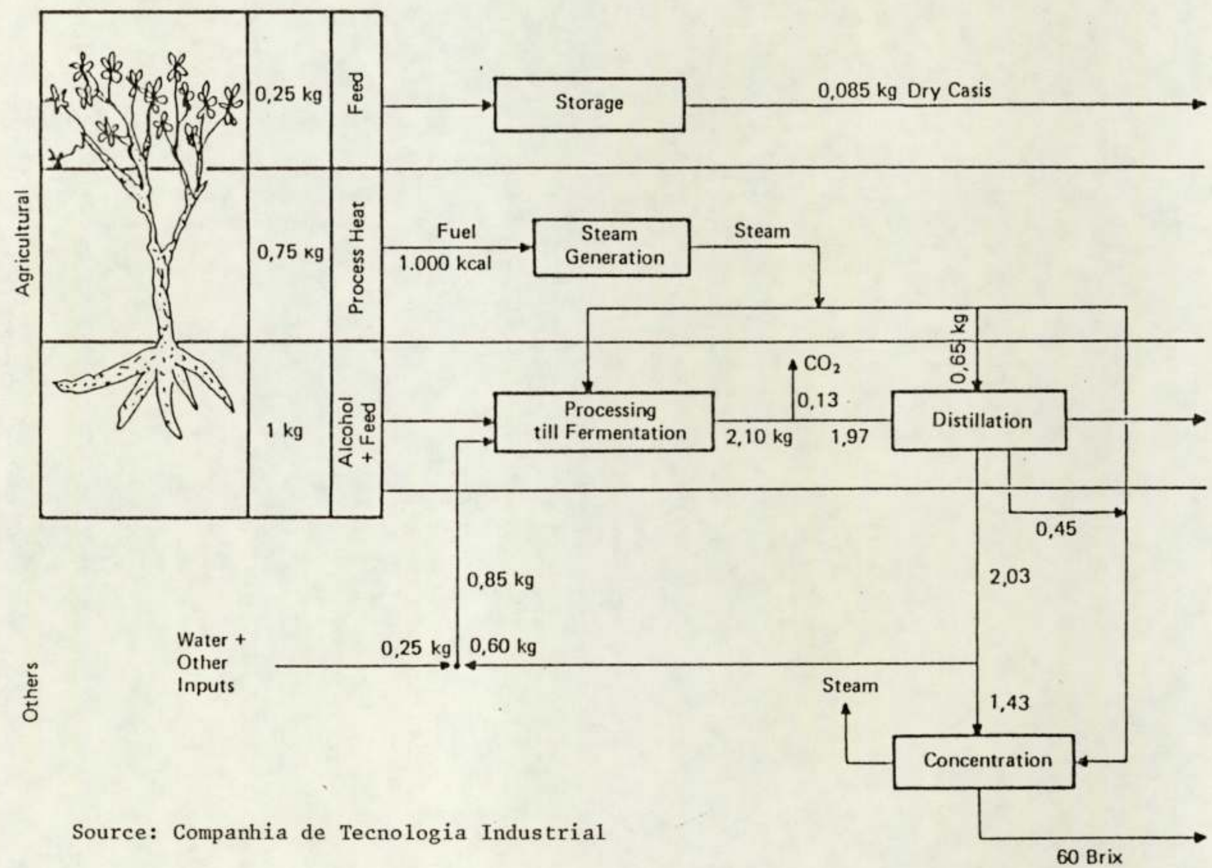
5.7 Cassava Alcohol Technology

The problems associated with the feedstock production were highlighted in 3.4. Cassava enthusiasts argue that technology for cassava-based alcohol is well developed in Brazil. This assumption is, however, open to challenge because there remain many industrial problems, particularly with large units, filter separation, ethanol losses, stillage concentration, low efficiency (71.5% of theoretical), etc. This is despite the fact that Brazil had a plant operating in the mid 1930s at Divinopolis, MG, with capacity of 5×10^3 litres/day, but all research was discontinued. The MIC has however set up the 'Companhia de Technolgia Industrial' (CTI), exclusively dedicated to the marketing and promotion of cassava-based alcohol production technology for units of 10^3 and 2.5×40^3 litres/day. The CTI has strong links with major research centres of the country, especially the INT and Embrapa's research network.

Unlike sugarcane, cassava does not have a seasonal problem and therefore the distillery can operate all year round and can use any other starchy raw materials. If the new administration in Brazil gives priority to cassava, as it seems to be willing to do, this could have a major effect, particularly in the development of small-scale alcohol plants. Fig. 5.1 shows a simplified scheme of a cassava plant for anhydrous alcohol. Despite recent research activity, this is an area where so much needs to be done. Recent advances include the use of 'Trichoderma reesei' to break down the lignocellulosic fibres of cassava roots which has allowed greater access to the starch for the amylases.[37] Five-day successful fermentation at 30°C and a pH of 3.5 ethanol yields of 82.3 to 99.6% of theoretical, were achieved.[38] But many of these advances are far from a commercial stage. Figure 5.2 summarises the major areas of research which need immediate consideration.

In Brazil most enzymes for cassava alcohol have to be supplied by foreign-owned firms - Novo Industri do Brazil with 60-70% of the market; Miles Laboratory and Pfizer Química. The only domestic firm was BioBras (Bioquímica do Brasil). Miles' Enzymes Production Division moved into Brazil in the early 1970s and had an expansion policy and plans to set up a plant to become operational in 1985 to produce the 'takatherm' and 'diazyme' L100 enzymes aiming at the ProAlcool market.[39] Pfizer has also been working since 1978 to hydrolize cassava starch 'in natura', with the alpha-amylase P500 and P250 enzymes.[40] But the state-of-the-art is well epitomized by BioBras. This company entered this market in the belief that cassava would play a major role within the ProAlcool, which did not happen. This, coupled with foreign competition and lack of government support, forced BioBras out of this area of research. The company had great success with its enzymes and was able to provide the enzymes for the Curvelo's plant. Recently BioBras was forced to sign an agreement with Novo Industri do Brasil according to which the latter will produce the 'alpha-amylase' and the 'amyloglucosidase'. Novo will transfer this know-how aiming at the alcohol and textile industries.[41] With this, Novo will further reinforce its market position. Thus Brazil is not only lagging

Fig.5.1.Simplified scheme of complete manioc utilization (Anhydrous Alcohol)



Source: Companhia de Tecnologia Industrial

Figure 5.2

Major Areas of Research Needed in the Production of Alcohol from Cassava.

Research Areas	Industrial Phase	Research Areas
Enzymes(amylase) Production of new microorganisms, plant process technology, purification, concentration and storage techniques. Kinetics.	Cooking, Starch separation	**Processes:** Temperature control, energy recovery, batch & continuous fermentation processes, separation of solid waste.
Enzymes(amiloglucosidase) Production of micro-organisms, plant process technology, purification, concentration and storage techniques. Kinetics	Saccharification	**Processes** Temperature control, batch & continuous fermentation processes.
Yeasts Selection of yeasts, genetic engineering, infections, nutrients optimum concentration immobilization, Kinetics.	Fermentation	**Processes** Batch with recycle, continuous with or without recycle, semi-continuous with recycle; new processes, greater alcohol concentration.

Source:

Queiroz de Araujo N. Mini-Usinas para produção de etanol. Revista Brasileira de Química Industrial, 52 (614) June 1983, p. 184, fig. 6.

behind other countries, notably Japan, on cassava-based alcohol technology, but it faces a situation of almost total dependence on foreign firms for the supply of enzymes too.

5.8 Cellulosic Technology

Brazilian attempts to produce wood-ethanol were described in 3.6.1 above. I shall concentrate here mostly on acid and enzymatic hydrolysis technology within and outside Brazil. The Uberlandia plant in Brazil, operates with diluted acids. The wood is chipped to 25 x 10x5mm. and hydrolised with diluted sulphuric acid. The hydrolysis process comprises (a) the impregnation in which the hydrolysis of the polysaccharides of easy hydrolization basically occurs and (b) the percolation during which the sugar formed during the impregnation is extracted and the polysaccharides of harder hydrolization are hydrolized.[42] The trouble is that significant losses occur in this acid hydrolysis step - i.e. 58% of the fermentable sugar theoretically present in the raw material is actually recovered.

This is, however, an area where extensive research is being carried out and significant advances may be expected, particularly in enzymatic hydrolysis. Acid hydrolysis in addition to being energy and capital intensive, is a well known process and new important developments are probably limited. Enzymatic hydrolysis technology, on the other hand, seems to be more promising because it allows fermentable sugar solution to be obtained immediately. Table 5.7 compares enzymatic and acid hydrolysis processes for cellulosic materials. Enzymes have been slow and expensive in the past but new enzyme strains said to be twice as effective as existing ones have been developed by the US Navy.[43]

Other technologies under active development elsewhere include decrystallisation-hydrolysis, hydrogen fluoride solvonlysis-hydrolysis, direct

Table 5.7 Comparison Between Enzymatic and Acid Hydrolysis Processes for Cellulosic Materials.

Acid	Enzyme
-Non-spcific catalyst therefore will delignify material as well as hydrolyze cellulose	Specific micromolecular catalyst therefore extensive physical and chemical pretreatment of material necessary to make cellulose available for degradation.
-Decompose hemicellulose to inhibitory compounds (i.e. furfural).	Produce clear sugar syrup ready for subsequent fermentation.
-Harsh reaction conditions necessary and therefore increased costs for heat and corrosion resistant equipment.	Run under mild conditions (50 atmospheric pressure, pH 4.8).
-High chemical cost require catalyst recovery and reuse.	Cost to produce celluloses is the most expensive step in the process, therefore recycle is necessary.
-Rate of hydrolysis is high.	Lower rate of hydrolysis.
-Overall yield of glucose is low due to degradation.	High glucose yield depending upon system and pretreatment.

Source:

Kosaric N. et.al. Ethanol Fermentation, Biotechnology, (H.Dellweg Editor). Basel, 1983, Vol.3, Chapter 3a, p. 315, table 21.

microbial fermentation, and delignification hydrolysis.[44] The problem facing Brazil, particularly Coalbra, is that a possible breakthrough in one of these areas may make its own acid hydrolysis process doomed to failure. This possibility has led to a call for postponement of any major decision for large-scale wood-ethanol, until the technology is fully developed, or new processes come on stream. There is also growing interest in producing methanol via electrolysis, for use in industrial rather than for fuel purposes, as noted above.

Already important improvements have been reported on the traditional recovery process, with considerable energy savings. Over 60% has been achieved.[45] Although most of these improvements are far from being transferred to industrial plants, such development must be fully monitored prior to any major commitment to produce wood-ethanol in large-scale.

In summary, one may argue that the research activities in the industrial countries in the area of process technology, particularly in the fermentation and distillation steps, are not matched by Brazilians. This is not to deny significant changes have taken place in the past few years in this area. One should be reminded that the alcohol industry has been a by-product of the sugar sector until relatively recently.

Fermentation technology is an area where Brazilians can easily lose ground, specifically in fermenter design and the development of new strains. More research on microbiology and enzymology would be needed, although the PRONAB aims to correct this weakness. A more serious problem is that of enzymes on which Brazil is largely dependent on foreign know-how. If the country is to diversify its raw material for alcohol production away from sugarcane, then the alternative would be starchy and cellulosic feedstocks. If, for example, cassava and wood was to be used in large-scale, then enzymes would need to become a priority research area if the country wants to avoid overdependence on foreign know-how.

With regard to distillation processes, despite the improvement of recent years, it remains basically too energy intensive. If the international market is in the mind of equipment manufacturers, then substantial improvements are still needed if Brazilian firms are to capitalize international opportunities. As for the stillage technology, the ProAlcool has created many new difficulties and challenges. This is an area where Brazilian firms are acquiring much expertise and know-how as a result of the programme, which has placed them in a unique position.

CHAPTER 6

END-USE: FUEL ETHANOL

Introduction

Despite considerable uncertainty about what would be the next major fuel of the future, alcohol fuels are currently the focus of a considerable worldwide revival. This stems from the facts that (i) alcohols can be produced locally and hence reduce the burdens of foreign exchange payments for petroleum imports; (ii) it is technically easy to use (i.e. it entails a minimum of adjustment to many engines now designed to run on petroleum fuels); (iii) alcohols could be competitive with petroleum-based fuels, at least in certain countries and circumstances; (iv) because of growing demand for unleaded gasoline.

Nonetheless, the widespread use of alcohol fuels depends on a combination of economic, technological and political considerations. In the particular case of Brazil and in spite of the present commitment to alcohol fuels, its long term consolidation would be conditioned by the world's energy situation. This is particularly true if one considers that the automobile industry is wholly owned by the MNCs, whose global strategy and investment continue to be with petroleum-based fuel engines. If oil prices remain steady or even fall, then strong government support would be needed to maintain the commitment to alcohol fuels, unless important technological breakthroughs can be made to reduce substantially the production costs.

In this chapter I will be mostly concerned with the main technological implication and developments of the alcohol-fuelled vehicles; consider the main alternatives under consideration to solve the diesel problem (vegetable oils, new additives and engines and fuel modifications); examine the use of alcohol in commercial vehicles, particularly trucks and tractors.

6.1 Historical

Consideration of the use of alcohol as automobile fuel is as old as the invention of the combustion engine itself. Nikolas Otto used pure alcohol in his first engine in 1897. In 1907 the USA Department of Agriculture published a report entitled 'The Use of Alcohol and Gasoline in Farm Engines'.[1] The widespread use of alcohol-fuel in the 1930s and early 1940s is a well known fact.[2]

After that, petroleum-based fuels gained their long dominant position because they were cheap and easy to handle. The steep rise of oil prices in the mid 1970s, commenced a world wide search for petroleum alternatives in earnest. Alcohol fuels are the focus of considerable worldwide attention which stems not only from oil price increases, but also because of foreign exchange considerations, the fact that they can be produced locally and because minimum adjustment requirements are needed to many engines now designed to run on petroleum fuels. In addition, the fuel distribution network can be readily utilized.[3]

At the same time the boosting properties of alcohols, together with the growing demand for unleaded gasoline, has further highlighted the interest in alcohol fuels. Indeed this is one of the most promising markets, particularly for ethanol because of its octane boosting properties.[4] In the USA, already alcohol blends constitute between 4.5% and 5.5% of the gasoline market. More than 30 states have provided either partial or complete state fuel tax exemption for alcohol blends.[5]

A conservative estimate of worldwide use of alcohol fuels, predicts a five-fold increase by 1995 - from 0.68×10^9 litres to 6.9×10^9 litres for methanol; and from 7.5×10^9 litres to 34×10^9 litres for ethanol per year.[6] Worldwide fuel consumption forecasts by the year 2000 is reckoned to be 50% petrol; 25% coal fuel; 15% diesel oil; 6% LPG and 3.5% ethanol from biomass.[7] These forecasts seem to exclude possible large scale use of alcohol blends in the EEC, a possibility now under consideration. Regardless of the accuracy of these forecasts, it does appear that the market for alcohol fuels is steadily expanding.

What many people are unaware of is that Brazilians have been using alcohol fuels since the early twentieth century, with ups-and-downs, as illustrated on Table 6.1. When the Brazilians commenced to produce alcohol cars in large-scale they already had decades of experience behind them.

The timing of expansion of alcohol fuels will depend on a mixture of political, technical and commercial factors. On the political side one could mention tax incentives, government mandates on fuel, discrimination tariffs; on the commercial side, lower production costs, commercialization of by-products; greater security of supply and demand, among others.

As for the technical factors, one must consider not just changes on petroleum supplies, but also technological development within the automobile industry itself. For example, advances in engine and fuel technology, could affect demand for alcohol fuels, through greater efficiency and the utilization of new fuels or poorer quality fuels. As petroleum supplies become more scarce and of poorer quality, a lot of research has gone to increase the engine's fuel tolerance. This would allow present gasoline and diesel engines to overcome some of the specific limitations, such as octane and cetane numbers, which severely limit their ability to use other fuels.[8]

Table 6. 1 Historical Evolution of Alcohol-Fuels in Brazil

1902	Publication of a document in Bahia on the industrial possibilities of alcohol.
1919	The State of Pernambuco made compulsory blendings of alcohol and gasoline in official vehicles.
1923	Experiments started at the Fuels and Minerals Testing Centre in Otto-cycle engines with neat alcohol.
1925	A Ford automobile runs the circuit Rio-S. Paulo-Rio on pure alcohol.
1927	Formed in Pernambuco a "pro-alcool" association which manufac tured "Azulina" (an alcohol and ester mixture).
1930	The University of São Paulo began to investigate alcohol fuel
1931	Decree No. 19717 made it compulsory to blend a minimum of 5% alcohol to gasoline. The Ministry of Agriculture created a commission to study alcohol fuels in automobiles.
1933	Decree No. 22789 creates the IAA which increases the interest for alcohol in combustion engines.
1938	Federal Legislation approves extending alcohol and gasoline blendings in Brazil.
1942	Decree No. 4722 considered the alcohol-based industry of national interest, and established the minimum price for alcohol.Alcohol & gasoline blendings reached 50% in some areas of the country.
1956	Alcohol & gasoline blends reached 40% in the Northeast of Brazil.
1960 /65	High prices of sugar in the international market and low petroleum prices, reduced the interest for alcohol fuel.
1966 /67	Decree No.59190 authorized the upper limit of alcohol & gasoline blends from 5% to 10%.
1974	Steep increases in petroleum prices, and the beginning of experiments by CTA with higher alcohol & gasoline blends.
1975	Decree No.76593 creates the PNA, whose main aim was to promote alcohol fuels.
1977	Beginning of fleet tests with 100% alcohol-fuelled engines Otto-Cycle in the CTA. Alcohol fuel displaced 5% of Brazil's gasoline demand. Blendings increased to 20%.

(Table 6.1 cont.)

1978	60% of alcohol production used as fuel.11% of Brazil's gasoline demand replaced by alcohol.
1979	Production of 100% alcohol-fuelled cars. 14% of Brazil's gasoline demand replaced by alcohol. Number of alcohol-fuelled cars sold: 8 134.
1980	Alcohol-fuelled cars reached 270 000
1981	Concern with possible shortages of alcohol.Introduction of negative meassures which resulted in lower demand. Fleet of alcohol cars : 153 000
1982	Fall in sales led to the introduction of new incentives to alcohol car.Fleet: 235 000.
1983	Dramatic increase of alcohol car sales. Total sold 590 000 Cummulative fleet:1 254 000. On 19 September the show "one million alcohol cars" was commemorated in Brasilia.
1984	Consolidation of the alcohol vehicle. 55% of Brazil's gasoline demand replaced by alcohol. Cummulative fleet reached near two million.

After decades of stability, the automobile industry has entered the technological race in earnest. Thus important technological advances can be expected. It is expected that the car of the 1990s would be completely different in almost every respect to the car of the early 1980s. The most important technical changes are likely to be in (i) power train electronics, with weight reduction up to 60% over similar steel components; (ii) new materials such as ceramics; (iii) greater engine efficiency[9] and, of course, greater legislation pressure to improve standards on emissions and safety. To this extent alcohol fuels, because of their boosting properties and their effectiveness in lowering vehicle emissions, are bound to play a greater role in the future regardless of oil supplies.

New engine developments can open up new possibilities. For example, new research is going on into the Stirling engines, because of their ability to use alternative fuels (i.e. they can use liquid fuels, such as alcohols; and solid fuels, such as charcoal, and coal, etc.). They have a high thermal efficiency and low pollution problems; and can use many ceramic components. Enthusiasts of the Stirling engine reckon that the next century could well be regarded as the 'Stirling engine century'.[10] Despite the fact that no commercial production has yet started, and the cost remains 20-30% higher than the Otto-cycle engine, the Stirling engine seems to remain a strong candidate for the future.[11]

In addition to alcohols (ethanol and methanol) there are other strong contenders, such as hydrogen gas. Hydrogen gas has many advantages. The raw material for its production, water, is readily available. It is non-polluting and renewable, since the product of combustion is water. Hydrogen can be stored and transported by mixing with natural gas, by liquification. It is used in the industrial production of methanol and ammonia; and can be used for the hydrogenization of biomass for upgrading its energy quality. Internal combustion engines, using H_2 fuel have already been demonstrated to new vehicles.[12] These are just some examples of how new technological advances could influence demand for alcohol fuels, one way or another, beyond oil supply considerations.

6.2 Brazil Automobile Industry

As stated in Section 1.4 this industry was to form the basis for Brazil's drive to industrialization - part of a broader policy strategy for rapid industrialization adapted by the Kubischek government in the mid 1950s. When the big MNCs moved in attracted by the potential of the Brazilian market and the need to avoid high tariff barriers on vehicle imports. The automobile industry in Brazil remains wholly controlled by European and American MNCs (there are no Japanese MNCs in this sector in Brazil) while Brazilians have to content themselves with playing a role in production of components only. Commencing almost from zero in 1955 Brazil is today among the world's largest automobile manufacturers.

The automobile industry, a major source of employment, required a massive state commitment, with enormous subsidies going to producers, and complementary facilities - e.g. to ensure the supply of basic items, roads, petrol stations, etc. This policy led to an overdependence on road transport and created many of the country's problems today, by preventing the creation of a more balanced transportation system.

Because of the high investment cost required to develop an alternative to the road transportation system, the main focus of the government policy now concentrates on: (i) improving the existing system; (ii) energy saving; (iii) alternative liquid fuels, mainly alcohol; (iv) limited electrification, chiefly of railways because of high investment costs.

The Ministry of Transport (MT), has also lost priority within the public investment sector. Total investment was reduced from 1.5% of the G.N.P. in

1979 to 0.6-0.7% in 1983.[13] However, road transport investment will continue to dominate the transportation system in Brazil because there are no plans in the short or medium terms to expand the railway system. Even the expansion of the agricultural frontier will be based on road rather than rail. This is despite the fact that already over 60% of all goods and 94% of all passengers transported in 1983 corresponded to road transport.[14] Thus, as things stand, road transport seems to continue to expand considerably in the future, depending of course on the general economic situation.

6.3 The Ethanol-powered Automobile Sector

The idea of the ethanol-fuelled car was opposed by the automobile manufacturers when it was first proposed. The MNCs dominated industry was not interested in such a car because its strategy and investment is based on the petroleum-based engines. The industry lacked experience with such a car, but most important, they believed that there was not any significant international market for the alcohol car. In this situation their exports could negatively be affected. Consequently, the industry did not invest in R&D and it was the government's Aerospace Technology Centre, which carried out most of the fundamental research. What finally forced the industry to accept the idea of the alcohol car was the combination of government pressure,[15] slump in car sales and financial incentives to the alcohol car.

Nonetheless the first cars came out with many problems, which seem to have been more the result of the carelessness of the manufacturers who would have been relieved should the car have proved to be a market failure. One must accept, however, the fact that there was not any infrastructure to support the alcohol car - e.g. experienced personnel, maintenance shops, alcohol fuels stations. Aguiar Puppo argues, for example, that the alcohol car had three main enemies: (i) the automobile industry; (ii) Petrobras; (iii) the complacency of the Federal Government.[16]

According to some critics, the government passed on the know how to the automobile industry totally free.[17] To a certain extent one could argue that the MNCs of the automobile industry, are using Brazil as a testing ground to improve or develop alcohol fuels technology and for which the country receives little compensation.

Government officials, however, deny this and argue that to control such know-how by the Brazilians would have been very difficult because: (i) the dominant position of the MNCs in this industry; (ii) the ethanol engines consist of many small adaptations rather than radically new concepts; (iii) most countries have developed or are capable of developing alcohol engines, the only major difference being the lack of market.[18]

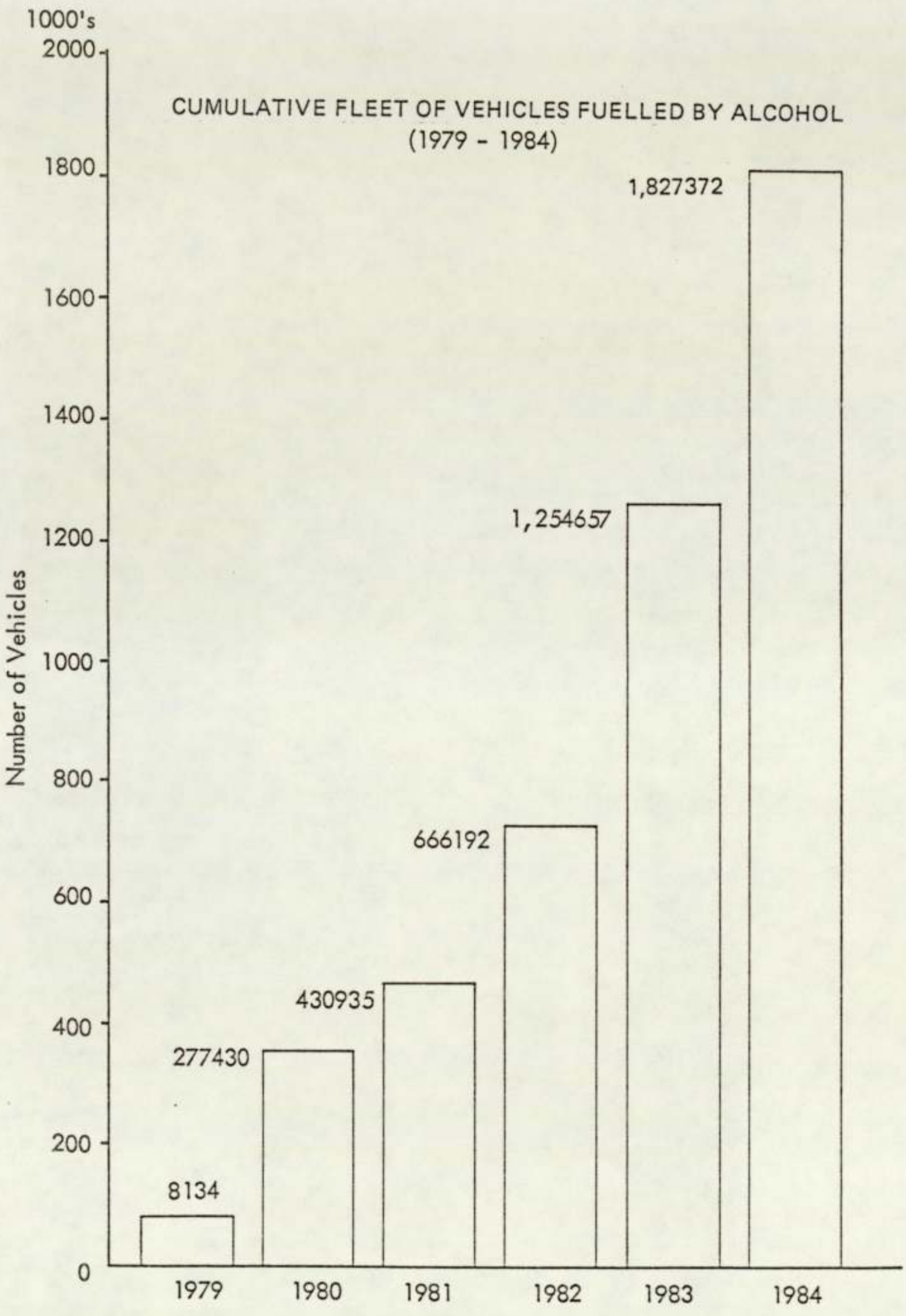
Despite this initial lack of enthusiasm, the alcohol car was a great success from when it was first commercialized. The reasons seem to have been: (i) government incentives (lower taxes, cheaper credit and longer repayment period for purchasing new alcohol cars); (ii) nationalistic motivation, since domestic fuel was used; (iii) safety of supply; (iv) economic impact due to price differentials between gasoline and alcohol cars. This price difference was proportionally larger than the difference on fuel consumption, due to the lower calorific value of alcohol. The National Energy Council (CNE) fixed the price of alcohol (this can vary) at 65% of the price of gasoline. However, the equivalent calorific value of ethanol is 80% of the gasoline, therefore the consumer has a price of advantage of 80-65 = 15%. In addition new alcohol car models have substantially improved fuel consumption and as a result the alcohol car owner has further increased his advantage over the gasoline car - he is between 11-29% better off.[19] However, it is possible that in the near future the price of alcohol could be increased or incentives to the alcohol car phased out or reduced (see Section 8.2.2).

It is quite remarkable that the automobile industry has been able to transfer 60 years of experience with the gasoline engine on to the alcohol car in just a few years. Figure 6.1 presents the cumulative fleet of alcohol cars from 1979 to 1984. The increase in the past few years has been, by any standard, quite remarkable. The market share by company and type of vehicle is illustrated on Table 6.2. In 1984 the alcohol car represented 84.1% of all cars sold in Brazil, or 94.6% if one considers passenger cars only; 57.2% of all light vehicles were also alcohol powered. By company, VWB occupies the first place with 41.55%, followed by GMB with 26.17%

It is important to recall that there has been an important shift of emphasis towards using alcohol in non-passenger cars, since the main technological obstacles are being overcome. This is important because the priority given to the passenger car has been a major source of criticism of the ProAlcool. The consolidation of the distribution network, which at the end of 1984 had 15519 petrol stations (79.3% of the total) selling alcohol,[20] could be regarded as equally impressive.

Finally, one may ask the question, who really has benefited more from the alcohol car? There remains some controversy about whether it was the consumer, the state or the industry. Critics of the ProAlcool argue that certainly the state has lost a lot of revenue through incentives, low taxes, etc. for the alcohol car. This, however, need not necessarily be the case because the state benefited from higher sales tax revenues, and higher employment which was maintained in the industry thanks to the boom in alcohol cars. ANFAVEA (The National Association of Vehicle Manufacturers) argues that the real beneficiary has been the consumer, since the higher revenues stemming from increased sales had to be put back into R&D, for which the industry received non-financial support from state resources. However, my understanding is that the real cost to convert from gasoline to alcohol cars,

Fig. 6.1



CUMULATIVE FLEET OF VEHICLES FUELLED BY ALCOHOL
(1979 - 1984)
1000's
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Number of Vehicles
8134
277430
430935
666192
1,254657
1,827372
1979
1980
1981
1982
1983
1984

Table 6.2 Participation of Alcohol-Fuelled Vehicle Sales, by Firm and Category, in 1984.

Firm	Units sold	Percentage
Volkswagen (VWB)	236 270	41.55
General Motors (GMB)	148 793	26.17
Ford Brasil (FB)	122 530	21.55
Fiat	59 888	10.53
Gurgel	465	0.08
Mercedes-Benz (MBB)	453	0.08
Agrale	107	0.02
S. Matilde	41	0.01
Puma	34	0.01
Farus	25	-
Total sales (all categories)	578 926	
Alcohol cars	572 100	84.30
-Passenger & mixed use cars	528 500	94.60
-Light vehicles	41 100	57.20
-Heavy vehicles (6 tons plus)	2 500	5.10

Source:
CENAL, Relatorio Anual 1984,CENAL 1985,pp. 31-33, tables 33-36.

was not very high.[21] The evidence seems to suggest that the consumer has been the main beneficiary of the alcohol car.

6.4 Main Innovations on the Alcohol-powered Vehicle

The main research efforts have gone into improving fuel efficiency, blendings, coating, etc. of the Otto-Cycle engine, but not changing the fundamental thermal principle of the engine, so to take maximum advantage of the thermal properties of ethanol. Most research took place within Brazil, but often the MNCs' branches in the country received technical support from the companies' headquarters. Because the Brazilian legislation prohibits provision of financial support for foreign-owned firms, the MNCs in this industry have to finance their own R&D.[22]

The first alcohol cars received few minor modifications. The original idea was to adapt the fuel to the engine rather than to modify the engine itself. But as it presented more difficulties than originally envisaged, the Otto-Cycle engine was modified to accommodate the fuel. At the same time efforts were made to improve the alcohol quality.

Although the existing economic engines are still engines adapted to burn alcohol, it is however, a new mechanical concept with 300 engine parts different to the conventional gasoline engine. The Otto-Cycle alcohol engine has a thermal efficiency of 36-38% against 27% of the equivalent gasoline (25% in Brazil) and could be further improved to c.42-45%, this will more than compensate for lower calorific value of ethanol.[23] Although many innovations need to be incorporated, particularly microelectronics, most technical problems caused by alcohol have been overcome.

Table 6.3 summarizes the main innovations of the alcohol car. There are four main phases in the development of the modern alcohol car - from the experimental stages, to the first agreement between the government and

Table 6.3 Major Technological Innovation Phases of the Alcohol-Powered car in Brazil.

First Phase, 1975-1979

Basic research carried out in the CTA, where previous experience dates back to the 1950s. It consisted mostly of an experimental fleet, particulary official vehicles. Most tests were carried with 10-15% alcohol & gasoline blendings, to improve engine performance. Tests with 20/80% alcohol & and gasoline blendings show little real engine improvements. Lack of component parts required major efforts to adapt the petrol engine to alcohol and to similar performance.
About 700 vehicles were tested. Major innovations:
Head piston(developed in S. Paulo University); increase in compression ratio; modification of the fuel distribution and electric systems.
Problems:
Poor adaption performance; cold-start difficulties; problems with the carburation system which demanded revision every 2-3000 km.; lack of infrastructure and low quality control.

Second Phase, 1979-1980

First agreement between the government and ANFAVEA was signed to promote the alcohol car. Creation of the CAT(Technological Support Centres) to provide technical support for the alcohol car and maintain standards. The automobile industry started to manufacture special components.
Major innovations:
Engine modifications; increase fuel efficiency; fuel system modifications; fuel pumps; coated carburators and fuel tanks; changes in the admission system; filters, piston head.
Market expansion of the alcohol car.

Third Phase, 1981-1982.

The greater understanding and experience led to rapid improvements Major concern with consumer comfort; expansion of the maintenance network and lower maintenance cost; improved fuel efficiency.
Major innovations:
Automatic electronic ignition; coated carburators and fuel tanks to protect against alcohol corrosion were more efficient; fifth gear added; improvement in component parts.

Fourth Phase, 1983 onwards

It reflects a consolidation of the alcohol passenger car. The main characteristics are : reliability and acceptability of the alcohol was not very high.[21] The evidence seems to suggest that the consumer has been the main beneficiary of the alcohol car.

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Fourth Phase, 1983 onwards

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(Table 6.3 cont.)

car among the consumers; greater comfort; improved fuel efficiency; greater attention to engine modification to take advantage of the thermal properties of ethanol.
Major innovations:
Introduction of microprocessors, cold-starting system; new fuel injection system; lighter materials; better fuel consumption and anti-corrosion materials.

Major innovation needed

To develop a new engine which can take advantage of the thermal properties of ethanol-e.i.greater thermal efficiency.
Direct injection (elimination of the carburator); better anti-corrosion materials;
to improve fuel mixture in the cylinder; to increase fuel efficiency.

==

Note:In reality no car runs on 100% alcohol since the Brazilian regulation stipulates that 3% of gasoline must be added to the alcohol for denaturation (to make it undrinkable).

Source: (Compiled from different sources, particulary from informaton provided by Fernandes Danna of the STI/MIC, in Brasilia).

ANFAVEA for mass production, market consolidation and maturity.[24]

Advances in materials have been very significant which has allowed most of the corrosion problems to be overcome, particularly in the fuel system. There were three main options open: (i) selection of new materials or protective coating, particularly for components in contact with alcohol; (ii) use of corrosion inhibiting and (iii) suitable treatment of alcohol so as to reduce its corrosivity. The first option appeared the most acceptable in the short-term. There were other possibilities but the industry generally opted for new materials or protective coating. The IPT (Institute of Technological Research) has played a significant role in testing these new materials.[25] As a way of illustration, Table 6.4 specifies the major components for gasoline and economic revision of Ford Brasil 5.0L and 1.6L models. As can be seen material modification are substantial in the fuel system.

Fuel quality and fuel consumption remain a problem despite the improvement of the last few years. In fact the STI/MIC has become quite concerned to improve average fuel consumption. The average km/litre in 1983 was 10.6 km/litre for gasoline and 8.5 km/litre in the case of alcohol, and that planned for the end of 1985 is 11.5 km/litre and 9.2 km/litre respectively.[26] This consumption is, however, much higher than in industrial countires, because fuel efficiency was not a priority research area in Brazil. In the specific case of alcohol fuel, some critics argue that Brazil must achieve at least 22 km/litre by the year 2000, failure to do so would add 5×10^9 litres of alcohol demand and remove Brazil from the forefront of alcohol engine technology.[27]

In addition to the MNCs of the sector, the STI/MIC coordinates a number of research projects, carried out in public institutions (INT, IPT, CETEC, etc.) in all aspects of the alcohol car. These range from engine and fuel modifications to environmental impacts of the alcohol cars.

Table 6.4 Material Specification of Major Components of FORD Models.

Component	Gasline Version	Alcohol Version
FUEL TANK		
Suction of Return Tube	Zinc plated steel	Brass tube with cadmium plate chromed
Resistance Box	Zinc plated low carbon steel	Low carbon steel with cadmium plate chromated
Float Lever	Zinc plated low carbon steel	Stainless steel
Fuel sender Flange	Zinc plated low carbon steel	Low carbon steel with cadmium plate chromated
Filter	Polyvinyldene chloride	Nylon carcass plus phosphor bronze screen
Filler Cap	Zamak 925	Zamak 925, tin plated
Cap Seal Retainer	Zinc plated/ low carbon steel	Tin plated low carbon steel
Lock Striker/ Spring	Zamak925 zinc chro- coating/plain high carbon steel	Zamak 925 tin plated/stainless
Tank Assembly	Terne plated(8-20% tin,remainder lead)	100% tin plated low carbon steel,100 mg/m2/side.
FUEL LINES AND FILTER		
Filter Element	Phenolic resin Impregnated paper	Same,with extended cure time
Filter Element Heads	Lead coated low steel	Tin coated low carbon steel
FUEL PUMP		
Tower and Cover	Zinc plated chromat- ed low carbon steel	Cadmium plated chromated low carbon steel

(Table 6.4 cont.)

CARBURETOR		
Body	SAE 302 aluminum	Same,chemical nickel plating,
Throttle Shaft	Black oxidized low carbon steel	Nickel plated low carbon steel
Power Jet Vacuum	Ibid	Brass
Poeer Jet Control Stem	Aluminum	Brass
Needle Valve Tip	Viton	Stainless steel
CYLINDER		
Valve Seats	Cast iron	Stainless alloy
Cylinder head Gasket	Asbestos facing, low carbon steelzinc plat ted cylinder,grommets	High resilience asbestos facing,stainless steel cylinder grommets
Intake Valve	SAE 5135	SAE 5135,aluminased head&face,flash chromed stems
Exhaust Valve	21-4	21-4N,aluminazed head&face,flash chromed stems.

Note: This is a summary of major components only.

Source:

Pinto F B P, Aspects of the Design,Development and Production of Ethanol-Powered Passenger Car Engines, Proceed. IV Internt. Symp. Alcohol Fuels Technology, Guaruja, Sao Paulo, 1980.

6.5 Alternatives to the Diesel Problem

In Section 3.7 I discussed some of the reasons why ProOleo failed to achieve its objectives. One cannot reasonably say that there is an alternative to the diesel problem, but many alternatives which require technical, economic and political solutions. I will examine the main alternatives under consideration - engine modifications, vegetable oils and additives.

The reasons for the enormous increases in diesel oil consumption since the 1970s are complex but the most important was price policy. The CNP kept the price of diesel artifically low (c.one third that of gasoline), which in fact was more attractive than the technical advantages offered by the Diesel-cycle if compared with the Otto-cycle engine. In other words, cheaper fuel price was the main consideration. In 1974, 56.6% of all trucks were diesel fuelled, but by 1980 this percentage reached 98.5% of the total[28] (see also 8.2.2).

The conflicting views between government and manufacturers, mentioned in 3.7 could be further summarized as follows. Firstly, there are those who want to alter the combustion process of the Diesel-cycle engine to make it more suitable for alcohol. These include the STI/MIC, the Grupo de Assessoria e Participacao (EAP, Empresa Metropolitana de Transportes Urbanos (EMTU), and some members of ABDIB. In the second group, the philosophy is to find a suitable fuel to the present conventional Diesel-cycle engine - e.g. through the development of an additional auto-inflammable, to produce the necessary cetane mixture increase. This seems to be the most suitable solution to existing engines, although there might be distribution problems and additive supply. This view is that of the major heavy vehicle manufacturers, particularly MBB.

The attitude of MBB is very important because MBB represents about 50% of Brazil's market for trucks and buses. The MBB arguments are: (i) Diesel engines with direct fuel injection do not only equip many Brazilian Mercedes-Benz trucks and buses, but they also represent the best possibility in terms of overall efficiency among the existing means of propulsion for commercial vehicles. These engines' high efficiency results from the Diesel combustion cycle's thermodynamic characteristics, which provide a better energy yield than other engine types. Even in an age of alternative fuels, the Diesel engine will remain highly efficient, and shows the lowest fuel consumption figures; (ii) over one million Diesel-cycle engine powered vehicles exist in Brazil, which will be able to operate alternatively on normal diesel fuel or 'extended' diesel fuel, on synthetic diesel fuel produced from coal or shale oil; or fuel obtained from vegetable oils and additivated ethanol fuel; (iii) the 'extension' of diesel fuel, as proposed by MBB in 1977 will not harm engine performances or durability; (iv) the use of these alternatives requires only simple alterations of the injection systems, which are necessary due to the different properties of the fuels; especially their heat value and their lubricant characteristics; (v) once the engine's injection system is converted to ethanol operation the vehicles will be able to use the original diesel fuel, the 'extended' diesel fuel or transformed vegetable oils, after only a recalibration of the injection pump. These advantages apply to Diesel engines of all known types and manufacturers.[29] However, it is becoming increasingly clear that the solution lies in engine and fuel modifications, particularly conversion from Diesel to the Otto cycle. As we shall see, there is a wide number of alternatives under consideration by both vehicle manufacturers and state institutions.

Despite the fact that the first agreement signed between the government and the industry to use ethanol in heavy vehicles dates back to 1979, the only firm commitment by the authorities is with the sugar and alcohol industries. That seems to have been due to three main reasons: (i) to rapid growth of alcohol production; (ii) need to cut further oil imports; (iii) more importantly, pressure from alcohol producers who are trying to find attractive markets for alcohol.

The CENAL Act No. 775 specifically conditions the financing of new distilleries to the need of using alcohol fuelled machinery. The objective is that by 1987 on, the sugar and alcohol industries should be using exclusively alcohol-fuelled equipment with special allowances for reduced quantities of diesel oil and dual-fuelled engines. This represents a very important step in pioneering the use of alternative fuels in agricultural machinery[29 bis].

Despite the complaints of the heavy vehicle manufacturers that this market is too small (c. 20^4 per year) to provide any solution to the diesel problem, already various engine systems are ready to enter this market. These include: (A) Otto-cycle alcohol engines, which include (i) original petrol engine design - GMB and VWB; (ii) original Diesel engine design - Ford B; (iii) especially designed for alcohol - CTA; (B) Diesel-cycle alcohol engines. These include: (i) alcohol + additive - MBB, and SCANIA; (ii) pilot ignition - MWM Motores Diesel LTA and Volvo.[30]

6.5.1 Engine/Fuel Modification

Among the engine and fuel modifications to deal with the diesel problem now under consideration, are the following: (A) changing the refining cracking system of Petrobras to produce the maximum diesel oil from each barrel of petroleum.[31] This option also includes the use of surplus naphtha, up to 10% blended with diesel oil. (B) Use of ethanol as diesel oil substitute, and for which there exist four main technical alternatives. (i) ethanol + additive; (ii) dual injection motor. This involves the use of small amounts of diesel to ignite combustion by the addition of a second injection pump. Alcohol and diesel are injected simultaneously. By this method approximately 85% of diesel can be replaced. However the extra cost and space required to accommodate the double injection system is a limiting factor; (iii) the glow plug, used as temperature control when the engine operates under variable load conditions. It consists of an electronically resistant device used for ignition in the Diesel engine conversion, which gives much greater stability than the spark plug ignition. Results so far are very encouraging with an incrased efficiency of 22%. The spark plug is being tested in São Carlos (S.P.) in indirect injection diesel engines; (iv) substitution of the Diesel-cycle by the Otto-cycle engine. This option is being promoted by the sugar and alcohol industry.[32] The most significant advantage of this option is the possibility of using their own fuels. This guarantees to the sugar and alcohol sector a price lower than that paid in the market. If on the other hand the price of diesel was to be increased more sharply, then ethanol would be an excellent alternative. The diesel-cycle engines are approximately 30% more efficient than the Otto-cycle, but are also more expensive and because the the Otto-cycle is more suitable for alcohol, appears a viable economic alternative.[33] (C) Development of a new engine or significantly modifying the Diesel-cycle engine so that it can be operated with the lower cetane and octane numbers; cheap and reliable. The CTA is developing such an engine. This project is scheduled to end in 1985 and the aim is to develop an engine of 220-240 HP (up to 40 tons) to take full advantage of the thermal properties of alcohol. The characteristics of the engine are 40% lighter and 30% cheaper than the diesel engine, although remaining basically an Otto-cycle engine.[34] Because the MNCs in this industry were not prepared to invest to develop such an engine just for the Brazilian market, the government has been the prime actor in this project. However it would be interesting to know if such an engine becomes a commercial reality, who really will exploit it since the government does not appear to have the necessary resources to commercialize such an engine in large-scale.

Another promising development is the PID (Pilot-Ignition-Diesel) engines, developed by MWM Brasil. The PID engine represents according to MWM, a new concept because it involves complex alterations. It is basically a dual injection engine with a thermal efficiency equivalent to 84% of a diesel engine, in the case of the PID 229 family. It was first commercially available in March 1983. The PID engine was fitted to the world's first alcohol-powered tractor (see 6.7). It works with transesterificated vegetable oil and can be retrofitted to use alcohol gasoline blends without loss of efficiency. The efficiency is 6.5% higher than the conventional diesel-cycle engine, but it is more expensive.[35] This can be a problem because the alcohol producers, the main market, may not be interested in saving a small percentage of fuel; but rather in the initial cost.

In addition to vegetable oils (6.5.2) and additivies (6.5.3), the use of gas producer and Diesel + methane in 60-100% blend is being investigated by Petrobras, IPT, etc. Table 6.5 summarizes the main engines and fuel changes in the Diesel-cycle engines that may be necessary to use alternative fuels. It is based on MBB data. Because the Otto-cycle engine when adapted to burn alcohol has a high efficiency, this appears to be one of the most promising alternatives. However there is opposition from Diesel engine manufacturers.

6.5.2 Vegetable Oils as Fuels

In spite of the problems highlighted in 3.7, vegetable oils remain one of the best available alternatives to diesel oil, in the near future. Vegetable oils are regarded by the government as an important strategic stock in case of a national emergency. Vegetable oils are an important commodity in Brazil, responsible in 1980 for $3.1 billion in export earnings.[36]

The use of vegetable oils in Diesel cycle is as old as the engine itself. In a book published in 1913 by Rudolf Diesel 'Die Entstehung des Diesel' (The Fundamentals of the Diesel Engine), the author described the feasibility of

Table 6.5 Possibilities of Using Alternative Fuels in Diesel and Otto Engines.

Main Engine Construction Modifications Necessary for Alternative Fuel Operation.

Diesel Engine	Otto Engine (Gasoline)
Required only simple alterations of the injection system	-Compression ratio (piston or cylinder head modification) -Intake and exhaust manifolds -Carburetor -Valves -Distributor advance curve -Cold starting device

Possible Fuels After Engine Modification

Fuel	Diesel Engine	Otto Engine(Gasoline)
Diesel	Yes	No
Gasoline	No	No
Ethyl Alcohol	No	Yes
Ethyl Alcohol plus Additive (c.5%)	Yes (with fuel flow adjusted)	No
Diesel plus raw gasoline(or naphtha) up to 30%	Yes	No
Diesel plus treated Vegetable oils (in variable %)	Yes (under development)	No
Treated vegetable oils (unmixed)	Yes (under development)	No

Note: Vehicle components (fuel-fed system, for example) will possibly have to be modified due to materials' compatibility to the new fuel type.
For the identical range, the fuel tank must be replaced by a larger one, proportional to the increase of alternative fuel consumption.

Source: Mercedes-Benz do Brasil SA.

vegetable oils for his engine. However the modern direct injection engine of today is quite different from that of Diesel's. Interest in vegetable oil fuels dates back to the 1920s. In 1925, Fonesca Costa, then Director of Fuels and Minerals Experimental Centre, carried out a significant number of experiments with vegetable oils 'in natura'. In 1942 the INT published the first experimental results with cotton oil, babassu oil and palm oil (dende), and diesel and vegetable blending with very positive results.[37]

A majority of vegetable oils have already been demonstrated as thermodynamically satisfactory diesel engine fuels, raising in the process a number of specification issues due to the particular combustion characteristics where they differ from petroleum middle distillate. In contrast with petroleum fuels, vegetable oils do not go through a refining process that fundamentally changes their chemical structure. However their use 'in natura' has proved unsuitable because of intense deposit formation in the chambers and on the injection nozzles. All solid matter must be removed; degummed to remove the phosphate content and filtered to normal fuel injection system levels. This of course further complicates the economics of vegetable oil fuels.

A large number of alternatives are currently being investigated in Brazil by both public and private institutions. However the three main alternatives with regard to the utilization of vegetable oils as diesel oil substitutes in Brazil are: direct use of vegetable oils; utilization of fatty acids; and chemical modification of vegetable oils.

The direct use of vegetable oils includes: (i) utilization of 100% vegetable oils; (ii) vegetable oils + diesel blends; (iii) vegetable oils + diesel + ethanol; (iv) diesel + additives. The utilization of fatty acids include the following alternatives: (i) fatty acids + additives; (ii) esters of fatty acids. These alternatives have been tested in diesel engines with good results, except that they appear incompatible with present lubricants in use today.[38]

The chemical modification of vegetable oils include two main alternatives: (i) oil catalytic cracking and (ii) thermal cracking of oil. The transesterification of vegetable oils into monoesters from methyl and ethyl esters of fatty acids, have been obtained through their catalytic reaction with methanol and ethanol.[39] The monoesters have proved to be technically a good alternative to diesel oil, because of: (i) their good mixability with diesel oil; (ii) heat content similar to that of diesel oil; (iii) adequate viscosity and cetane numbers; (iv) high degree of compatibility with existing technology and systems.[40]

However there remain some technical problems due to (i) incompatibility with some raw materials; (ii) deterioration of the monoester during storage or transportation; (iii) excessive dilution of the lubrication oil by the fuel in the DI engines; (iv) higher cost due to the transesterification process, though economic processes are being developed.[41]

The utilization of neat vegetable oils appear only feasible in indirect engines, according to Ventura et al, although it has not been fully established yet whether this is true with all vegetable oils.[42] The problem with the indirect injection engine is that it involves a penalty in fuel consumption which makes it unsuitable to compete with direct injection engines. There are also technical problems - i.e. deposit formations in the combustion chambers, emissions, etc. The suggestion that hardware modifications could provide some solutions to these problems has been particularly opposed as we have seen, by MBB, on the grounds that more substantial improvements could be gained by changing the neat structure of vegetable oils.[43]

Without any question this is an area of intense research interest with practically all vehicle manufacturers involved in one or another. In addition other official institutions, such as Embrapa, INT, etc. are also carrying out experimental research and run fleets with different types of vegetable oils and proportions. Despite policy disagreements and lack of coordination, important advances have already been made. One such advance is the development of a new fuel called 'alcooldiesel'.[44] Although many of these achievements remain far from becoming a commercial reality, this is often for economic and political reasons.

In fact there seem to be too many options under consideration which have resulted in confusion and indecision by the conflicting arguments put forward in favour or against the proposed solution. Although one cannot deny that all opportunities should be explored, a more realistic option would be to define priorities more realistically. Table 6.6, for example, summarizes the results of research carried out by only one vehicle manufacturer with vegetable oils - VWB. It is only quite recently that the government has made a more serious attempt to try to coordinate and define priority research areas. The STI/MIC who coordinates this area of research, has set up a Technical Commission (OLEG-1) in order to coordinate and further research on the different aspects of vegetable oils; blending, etc.[45] However, this is an area where most firms carry out their research on an individual basis, particularly the large manufacturers, if only because there are policy disagreements.

6.5.3 Additive Research

Research on additives is becoming increasingly important, especially in the USA and Western Europe, due to growing demand for unleaded gasoline. Alcohols and more specifically ethanol, are attractive candidates to replace tetraethyl lead and tetramethyl lead, because of their properties as gasoline extenders and octane enhancers. Besides the environmental concern, there appear to be sound economic reasons for using alcohol gasoline blendings. Although there are many different estimates of refinery energy savings from

Table 6.6 Results with Vegetable Oils in Direct and Indirect Injection Engines.

1) Vegetable oil "in natura"

Unsuitable due to the intense deposit formation in direct injection engines.

2) Methyl ester of soya bean

Feasible with minor modifications in direct injection engines (e.g nozzle-injectors)

3) Diesel oil plus vegetable oil "in natura".

Unfeasible due to intense formation in direct injection engines. There exist the possibility of blending small quantities of vegetable oils "in natura" (approx. 5%) with diesel oil.

4) Diesel oil plus methyl ester of soya bean.

Viable in blending <30%.Over this proportion, the direct injection engines require small modifications.

5) Methyl ester of soya bean plus alcohol.

Viable, but engine modifications are required to prevent the fuel to become too diluted in the lubricating oil.

6) Diesel oil plus vegetable oil "in natura", plus alcohol.

Further test are required to reach any firm conclusion.

Note:

A problem with vegetable oil, pure, transesterificated or in blends, is that it requires minor modification of the engine because the unsuitability of present lubricants.

Source: Falcon A M. et.al, Utilização de Alternativas de Combustiveis a base de Óleos Vegetais em Motores Diesel de Injeção Direta e Indireta, lo. Simposio de Engenharia Automotiva, Brasilia, 26-27 July 1983.

the use of ethanol as octane boosting additives, the evidence suggests that large energy savings are possible. The OTA (Office of Technology Assessment) of the USA Congress estimates that between 40 to 45 x 10^3 BTUs of energy are saved for each American gallon of ethanol blended in 10% gasoline.[46] The total energy saving depends on the average octane of the refinery gasoline pool, octane boost assumed and the ratio of gasoline to middle distillates produced by the refinery, etc.

In Western Europe, it has been estimated that a complete changeover to 95 RON unleaded gasoline will require an investment of $2.7 billion to modify the present refining structure.[47] This is why Brazilian experience with alcohol fuels should be of great interest to countries planning to use alcohol as boosters. In Brazil many tests have been carried out to establish the validity of ethanol as an octane enhancer and gasoline extender.

The Brazil findings so far, demonstrate (i) a lower consumption of fuel due to a reduction in the refining process to obtain gasoline of higher octane number; (ii) non-utilization of tetraethyl lead as octane enhancer.[48] Figure 6.2 illustrates the results obtained with ethanol (anhydrous alcohol) as an octane booster. A 5% blend to 72 MON gasoline increases the octane rate of 74 and a 20/80% ethanol gasoline blend increases the MON to 80.3. The rating depends on the basic composition of the gasoline pool.

In addition to alcohol and vegetable oils, an important number of other additives are also under investigation, to be used in blends with diesel oil in various proportions. Many of these additives remain in an experimental stage, and hence it is difficult to predict the final outcomes, or to provide full details. However some of this research appears very promising. Table 6.7 conveniently summarises the most important developments in this area of research. Practically all heavy vehicle manufacturers are involved, state institutions such as the CNP and IPT, and other private institutions such as

Fig. 6.2 ETHANOL AS OCTANE BOOSTER

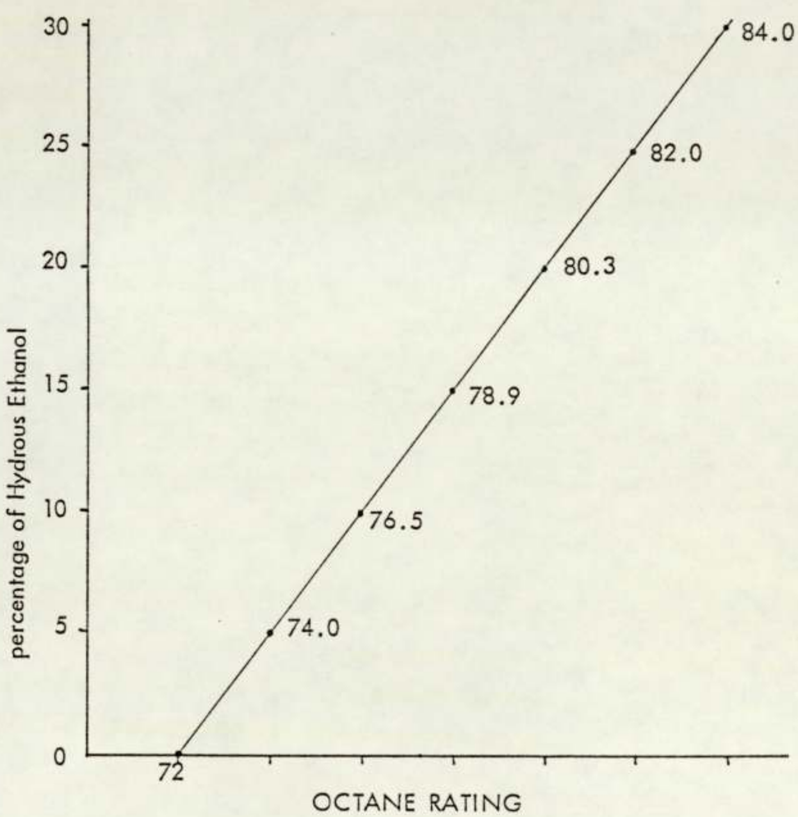


Table 6.7 Summary of Research on Main Additives.

Tetrahydrofurfuryl Nitrate (THFN)

It can be obtained from sugarcane bagasse or any other raw materials containing pentoses (e.g. straw.cotton seed, rice husks, corn cobs,) industrial fibrous waste etc.
Produced by "Industrias Quimicas Taubaté (IQT)
Uses: 7% blend with diesel; ignition improver in diesel oil. It can be used in gasoline/diesel blendings; gasoline & anhydrous alcohol; or in alcohol-fuelled vehicles.It can be use with hydrated alcohol in Diesel-cycle engines.
Increases of 18% in the octane number have been obtained.

Tri-ethylene Glycol Dinitrate (TEGDN)

It can be obtained from alcohol via ethane and subsequent nitration by conventional means.
Produced by Oxiteno/Britannite.
It is a good cetane improver. It can be used with most commom alcohols (ethanol and methanol). A conventional direct injection engine requires <5% in volume to run smoothy in the whole range of speed and load. Its cold starting characteristics are good.
The performance so far has demonstrated to be similar to diesel oil but consumption is a little higher.
It is expensive but production costs can be reduced considerably.

Ethylene-Glycol-Dinitrate (EGD)

Also widely being tested in blends of up to 5% with diesel oil.
Produced by Oxiteno/Britannite.

Ethyl-Hexyl-Nitrate(2-EHN)

It is also produce from renewable materials.
It is blended with diesel oil in proportion of up to 12 %.
Manufactured in Brazil by IQT.

(Note: This information has been collected mainly from Mercedes-Benz do Brasil sources).

SOPRAL and IQT (Industrias Quimicas Taubate).

The table excludes other more traditional automobile additives, such as the Tert butyl ether (TBA), widely used as an antiknock additive. Methyl butyl ether (MTBE) which has received great attention in the past few years, particularly outside Brazil, due to its blending characteristics close to those of hydrocarbons in gasoline. Another important additive widely used in Brazil is the Diesel-Ignition-Improver 2-ethyl, 2-hexyl nitrates (DII-2), produced by Ethyl Co. (USA), and in Belgium.[49]

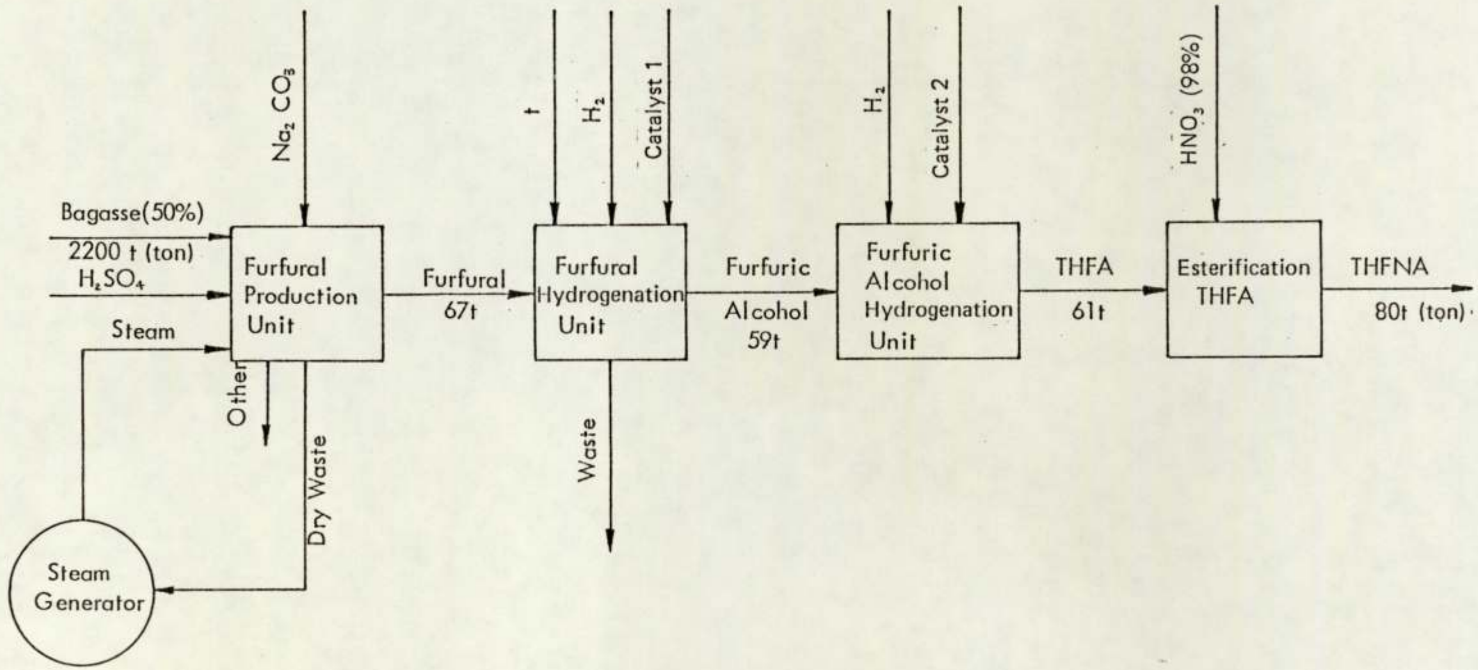
Of particular interest is the tetrahydrofurfuryl nitrate (THFN) additive which is based on tetrahydrofurfurilic alcohol produced from furfural. The furfural is obtained from sugarcane bagasse by a process developed in IQT. Figure 6.3 illustrates a simplified diagram for the production of 80 tons of tetrahydrofurfuryl nitrate alcohol (THFNA) from sugarcane bagasse.[50]

According to the IQT, the THFN fulfils two objectives: (i) as an additive to improve the cetane number of Diesel oil and (ii) as an additive with ethanol to be used in Diesel-cycle engines. Although the production costs are high, the scope for improvement seems to be large and the technology is already available.[51]

6.6 Alcohol Fuelled Trucks

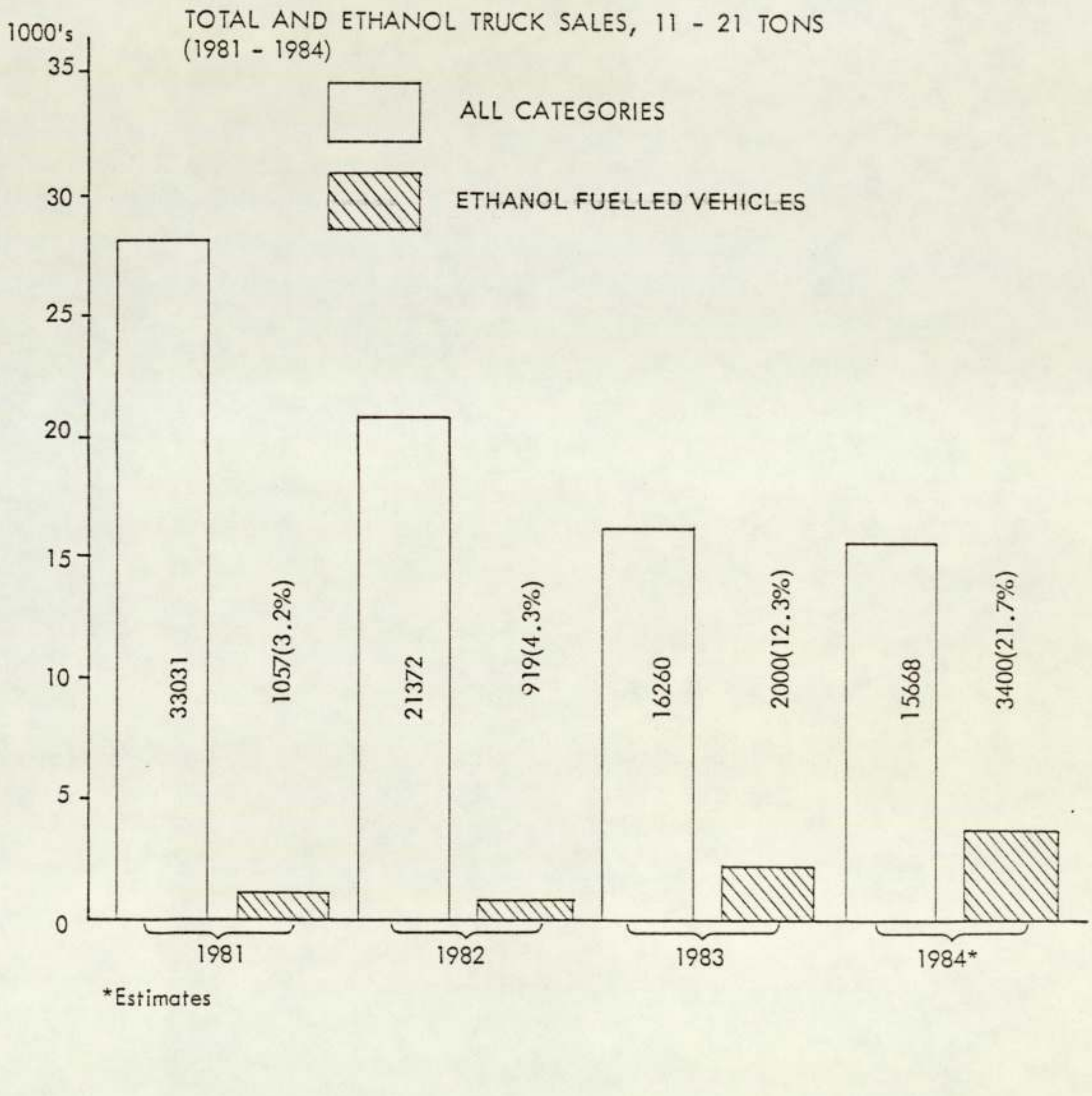
Despite the pressure of the ANTC (National Association of Road Haulage) to give priority to the utilization of alcohol in trucks and buses rather than in passenger cars,[52] the use of alcohol fuels in heavy vehicles has been a slow process. This seems to stem from two main reasons, (i) resistance from the vehicle manufacturers, (ii) technical difficulties and political indecision. Figure 6.4 shows the participation of total sales of alcohol trucks between 11 to 22 tons. This increased from just 3.2% in 1981 when the first commercial model

Fig.6.3. SIMPLIFIED DIAGRAM SHOWING THE PRODUCTION OF 80 t/month OF TETRAHYDROFURFURYL NITRATE ALCOHOL (THFNA) FROM SUGARCANE BAGASSE.



Source: INDUSTRIAS QUIMICAS TAUBATE. S.A.

Fig. 6.4



TOTAL AND ETHANOL TRUCK SALES, 11 - 21 TONS
(1981 - 1984)
1000's
35
30
25
20
15
10
5
0
ALL CATEGORIES
ETHANOL FUELLED VEHICLES
33031
1057(3.2%)
21372
919(4.3%)
16260
2000(12.3%)
15668
3400(21.7%)
1981
1982
1983
1984*
*Estimates

came to the market to an estimated 21.7% in 1984. These figures do not include light trucks as shown on Table 6.2. Considering that just a few years ago this sector was totally dominated by the diesel oil vehicles, it is a remarkable achievement.

The most important manufacturers of heavy alcohol vehicles are VWB with 52.2% for the 1981/84 period; GMB with 36.2% and MBB with 15.8% for the 1983/84 period.[53] The first commercial trucks were VWB and GMB, specially designed to meet the needs of the sugar and alcohol industry market. Both companies opted for the Otto-cycle as stated above, 100% hydrated alcohol. VWB's first model was the E13, 13 tons (dwt) and the E21 (20.5 dwt) first commercialized in 1982, with a new model of 6 dwt commercialized in 1984. GMB's first model was the A60, 11 dwt. The MBB initiated its participation in this market with the 22 dwt L22/3 model; and Ford B. in 1984 with the F22000 model, powered by MMW PID engine in proportion 10/20% diesel oil and 90/80% ethanol.[54] Scania has also entered this market with a T112E model.[55] and Volvo is expected to launch its first commercial model in 1985.[56]

The commercial viability of alcohol trucks have not been fully established, because despite the many tests carried out, many of these models are still in an experimental stage. On the other hand, the number of options being considered and the number of models used are considerably large and the operational conditions quite different, to make overall generalizations. According to CENAL the cost of the alcohol-fuelled trucks vary from 5% cheaper to 7-8% more expensive than its diesel counterpart.[57]

Studies by the STI seem to suggest that, on the whole the competitiveness of the alcohol vehicles depend on price differentials between fuels , type of vehicle, tax concessions etc. The main problem is that diesel oil remains relatively cheaper than any other fuel (see 8.2.2). As Fonseca puts it, 'the main obstacle to the utilization of alcohol in heavy vehicles is the price of diesel oil - whether we use the Diesel or Otto cycles, not the technology.'[58] Figure 6.5 compares fuel consumption of different alternative fuels with that of diesel oil. In all alternatives ethanol consumption is much higher. The best alternative to diesel is blending of diesel + vegetable oils, and then gasoline + diesel blends. However these estimates seem to compare too unfavourably with other studies, which show lower consumption when using ethanol.[59]

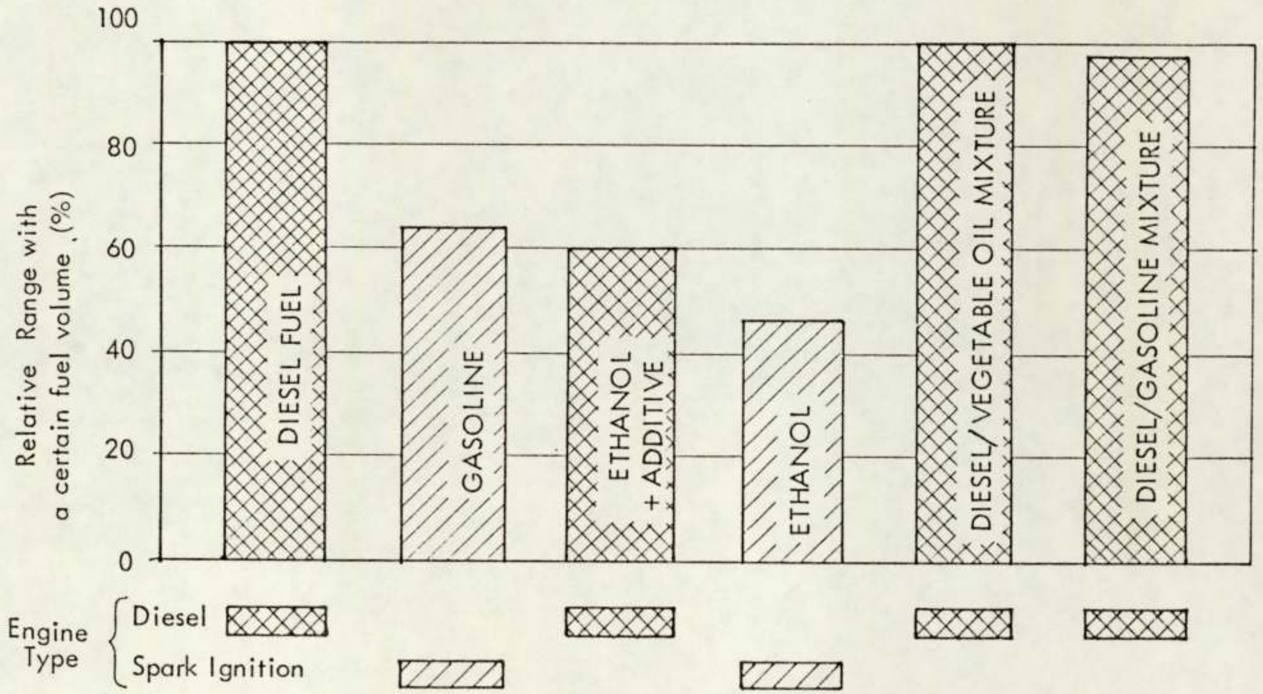
Moreover it appears to be necessary to alter significantly the present price structure of fuels to make alcohol fuelled vehicles more competitive. This, however, is likely to be strongly resisted by the supporters of diesel oil - e.g. the manufacturers of diesel engines and users.

6.7 Alcohol Powered Tractors

As with alcohol trucks, the tractor did not receive any financial investment or priority in the early years of the ProAlcool. The first tests with an alcohol-fuelled tractor were carried out in 1979 with a CBT 2100/2105 model fitted with a Dodge V8 engine of 112HP. Experiments were carried out by 'Companhia Brasileira de Tratores' (CBT) in cooperation with VW Cominhoes. They developed the CBT-3000 model in 1980, the world's first Otto-cycle tractor powered 100% by ethanol,[60] commercially available since 1982.

The wide acceptance of the CBT-3000 prompted other tractor manufacturers to convert their models to alcohol. In 1983 the commercialization of alcohol tractors increased dramatically. From October 1982 to March 1984, c.1400 alcohol tractors for agricultural purposes were manufactured. During the first term of 1984 alcohol-powered tractors represented 7.3% of all tractor sales in the country - a 400% increase.[61] Table 6.8 shows sales of alcohol-fuelled tractors by firm for the period January

Fig. 6.5 .BRAZILIAN COMMERCIAL VEHICLES RANGE WITH ALTERNATIVE FUELS (Diesel fuel = 100%)



Source: Mercedes-Benz do Brasil S.A.

Table 6.8 Distribution of Alcohol-Powered Tractor Sales in the First Three Months of 1984, by Manufacturer.

Manufacturer	Model & HP	Sales	Percentage
Valmet	88-79 HP	151	29
Valmet	118-118 HP	3	0.6
Valmet	118/4-118 HP	124	24.4
-TOTAL VALMET		278	54.8
Massey Fergusson	290-79 HP	176	34.7
Massey Fergusson	290/4-79 HP	8	1.6
-TOTAL M.FERGUSSON		184	36.3
C.B.T.	3000- 111 HP	16	3.2
Ford	4600- 66 HP	29	5.7
Grand Total		507	100.0

Source:
ANFAVEA; CENAL ProAlcool Relatorio, (January/February 1984) p. 18, table 20.

to March 1984. In the first place is Valmet with 54.8%, followed by Massey Fergusson (MF) with 36.3%. MF, Ford and CBT use an Otto-cycle engine 100% alcohol and Valmet models use the Diesel-cycle PID model developed by MWM in 90/10% alcohol/diesel blends.

Although the alcohol tractor does not involve any new revolutionary concepts, it does represent, nonetheless, an important development for two main reasons. Firstly, it represents a diversification of the market for alcohol fuels, which is socially more acceptable. Secondly, it could have a significant impact in many remote areas, because the farmers would be able to produce their own liquid fuels and gain considerable autonomy.

In summary, the automobile industry in Brazil presents special characteristics, because of the presence of heavy foreign capital, whose interests are not necessarily complementary to those of Brazil. Hence if alcohol fuels do not represent the best interests of their industry, opposition will grow. These MNCs are strong enough to make their views known. This is likely to be so if oil prices remain steady or fall, in which case there must be a strong political commitment to maintain alcohol fuels. However, although oil prices may fall further, the real cost may actually increase.

The automobile industry is expected to undergo radical change in the future. Such technical changes should not escape our attention when considering energy policy options. The automobile industry has enormous ramifications in Brazil and all the signs are that its importance will increase in the future, since no other serious alternatives are under consideration.

The ProAlcool remains, so far, the best testing ground for improving and developing alternative alcohol fuels technology. Already very significant advances have been made, particularly in engine efficiency, fuels and anti-corrosion materials. But greater improvements are still needed, on all fronts, to reduce investment costs.

A high proportion of research, however, is being undertaken by MNCs of the automobile industry in Brazil and in other countries. Thus it is difficult to know to what extent the Brazilians actually lead the field of alcohol fuel technology, other than in accumulated experience. Although the Brazilians themselves are very much involved too, it does appear to me that most of the know-how remains in the hands of these MNCs, except in specific cases - e.g. the CTA project on alcohol engines, which is still in an experimental stage. Therefore it appears that the main Brazilian contribution was confined to political and technical support. Once the political decision to use alcohol was made, the engine modifications were carried out by the vehicle manufacturers themselves. Indeed it does appear that without the considerable expertise and know-how of the industry (though not necessarily with alcohol fuelled cars) these modifications would not have been possible, at least in the short-term. Brazilian research centres are notoriously slow in producing commercial products. One should be reminded, however, that the alcohol engine suffered minor modifications only. Technically, it did not represent a too difficult task.

The extent to which Brazilian institutions have contributed to these technical modifications is not very clear. On one hand these centres carried out most of the experimental research. Indeed such know-how allowed the government to make the political decision to use alcohol fuels. But at the same time most of the actual innovations were introduced by the MNCs. Because of the enormous involvement of foreign firms in the automobile industry in Brazil, as seen in this chapter, it is difficult to know whether the success has been due to Brazilan determination and expertise, or to the MNC's ability to respond to the specific political and market circumstances of Brazil.

It is possibly safe to say that the main genuine Brazilian contributions would come from the alcohol production side rather than in alcohol fuel technology, if one considers all these factors. With regard to the shift of emphasis towards using alcohol fuel in commercial vehicles, this represents a significant social and technological betterment. In the first place because it makes the programme socially more acceptable and secondly because of what it can represent to many farmers to be able to produce their own fuel. Albeit the diesel problem is far from being solved, the alternatives now under consideration may ultimately be able to provide a more satisfactory solution. Such an outcome would be of extreme importance to many other countries.

CHAPTER 7

END-USE: CHEMICAL FEEDSTOCKS

Introduction

In the case of the alcohol industry one can distinguish two distinct historical phases. First is the pre 1975 phase in which the feedstock was very cheap, so far as the alcohol was a by-product of the sugar industry. A further characteristic was the erratic demand for alcoholchemistry products. Second is the post 1975 phase in which the alcohol industry commenced an unprecedented expansion and modernization drive. At the same time the massive use of alcohol fuel forced the price up, since alcohol production was not any longer a marginal activity. As a consequence government had to subsidise the feedstocks to allow the industry to compete with petrochemicals. This situation also coincided with an enormous expansion of the petrochemical industry.

In this chapter I analyze: the historical evolution of the alcohol chemical industry; installed capacity and processes; some political and economic issues; specialty chemicals and the perspectives for this industry.

7.1 General Considerations

Over the past forty years, the chemical industry has undergone revolutionary development. There are two basic factors involved: (i) the changeover from largely coal-based chemical technology; (ii) a more than one hundred-fold increase in output. In 1940, for example, 95% of the organic chemicals then produced came from coal and only 5% from petroleum.

However by 1978 only 3% originated from coal, whereas 97% was petroleum based.[1]

Since the oil shock of the 1970s, many new alternatives have actively been pursued. The need to find alternative raw materials in the chemical industry is evident if one considers the industry's heavy reliance on petroleum feedstocks. This reliance raises a number of problems, one of which is the fluctuating cost and uncertainty of petroleum supplies. Commodity chemical prices are especially sensitive to the cost of petroleum because feedstock cost typically represents 50-75% of commodity chemical manufacturing cost.

Among the options which are, or can be, pursued include: (i) the development of synthetic fuel from natural gas; (ii) conversion from biomass to fuels and a wide variety of organic chemicals.[2] Although non-renewable sources such as coal would probably be adopted earlier, particularly in the industrial countries where the technology is more advanced, biomass could be regarded as a major long-term alternative to the chemical industry.[3]

A shift from petroleum-based processes to bioprocesses for the production of commodity chemicals would be difficult, however, because of the existing infrastructure of chemical and energy production. This infrastructure allows a barrel of oil to be converted to products in a highly integrated system in which the by-product of one reaction may form the substrate of another reaction. Nonetheless biomass is used already as a source of several industrial chemicals, including dimethyl sulphoxide, rayons, varillon, tall oil, paint solvents, tanning and specialty chemicals; paper production, cellulose acetate and nitrates and other cellulose derivatives.[4] In fact every petroleum-derived chemical currently being used could be produced from biomass and non-petroleum minerals.

There are three main approaches to the transformation of biomass to useful chemical feedstocks: (i) chemical, e.g.

pyrolysis; (iii) biological, e.g. fermentation. Many of the most used chemicals are oxychemicals that have been or could be produced by microbial fermentation with or without chemical processing. Fermentation microbiology has the potential to produce a large fraction of oxychemicals. So far ethanol is the only fermentation oxychemical that is economically competitive with the corresponding industrial compound produced by synthetic means from fossil fuels.[5]

There are three main processes for producing chemicals from ethanol: (i) dehydration; (ii) dehydrogenation; and (iii) oxidation. In general, the use of fermentation ethanol would be relatively more economical for products involving oxidation and dehydrogenation than for those involving ethylene production by dehydration of ethanol. Oxidation and dehydrogenation processes give ethanol higher value than ethylene whereas in the dehydration of ethanol the opposite is true. However, all three ethanol conversion processes are currently designed for small-scale production, compared to the modern ethylene based processes which involve very large plants to take full advantage of the economics of size and scale.[6] Except in Brazil and to a lesser extent in India, the chemical industry remains fundamentally based on petrochemical feedstocks and even in these two countries the proportion of chemicals obtained from fermentation ethanol is relatively small compared with the petrochemical sector.

7.2 Historical Evolution of the Alcoholchemistry Industry in Brazil

The ethanol-based chemical industry or 'alcoolquímica' has a long tradition in Brazil, going back to the 1920s. The historical evaluation of this industry has conveniently been summarized in Table 7.1. Beginning in the 1920s with the manufacture of perfume-sprays of ethyl chloride obtained from ethanol, four main phases can be distinguished. The first comprises up to the early

Table 7.1 Historical Development of the Ethanol-based Chemical Industry in Brazil.

1920s

Origins of the alcoholchemistry industry. Elekeiroz, Usina Colombina and Cia Quimica Rhodia, all installed in SP,started to manufacture perfume-squirters based on ethyl chloride from ethanol Rhodia also manufactured, in small quantities, acetic acid and ethyl ether.
In 1929 Cia Brasileira Rhodiceta was set up which in subsequent years commenced to manufacture cellulose acetate using acetic acid anhydrate, the latter also synthesized from ethanol.

1940s

During this decade the following ethanol-based products were manufactured: ethyl chloride, ethyl ether, acetic acid and actic anhydrate.

Early 1950s

Increasing demand for plastic products stimulated the ethanol-based industry.This was also partly due to insufficient production of ethylene to meet the demand of the first petrochemical plants in Brazil.
Usina Victor Sense (RJ) manufactured butanol, alcohol acetates, acid acetic and ethyl acetate.

Late 1950s

Abundance of molasses in large quantities and at very low cost, further estimulated the expansion of this sector.
In 1958 Union Carbide started to produce ethylene to supply its low density polyethylene plant.
In 1959 Cia Brasileira de Estireno also manufactured ethylene and in 1959/60 Rhodia manufactured acetic acid, acetic aldehyde, ethyl acetate.
Other products manufactured at that time included vinyl acetate, soda, chloride, butadiene and 2-ethyl hexanol.

1960s

Abundant and cheap raw materials (molasses) permited the production of alcohol on large scale at marginal costs.This situation encouraged the ethanol-based industry to set up large projects.In the 1960s the industry expanded and diversified very rapidly.
In 1962 Industrial Quimicas Eletro Cloro started ethylene production by means of ethanol dehydration to meet requirements of its high density polyethylene plant.
In 1962 Rhodia started to manufacture vinyl acetate employing acetylene and acetic acid, obtained from ethanol.

(Table 7.1 cont.)

In 1965 Cia Pernambucana de Borracha Sintética-COPERBO, started to produce butadiene from ethanol, based on an Union Carbide's Second World War process.It also produced acetaldehyde.In the same year, Butilamil in Piracicaba , also started to produce butyl acetate and ethyl acetate.
In 1969 Elekeiroz do Nordeste began to manufacture 2-ethyl hexanol, by means of an intirely ethanolchemical route; and butanol , acetic acid and ethyl acetate were also produced in the same unit as by-products. In that year Butilamil started the production of acetic acid.

Early 1970s

Difficulties with raw materials (alcohol) supply and increasing costs (due to the favourable conditions in the international market for sugarcane molasses) forced some ethanol-based plants to close down. Many of the products could not compete with similar ones of the petrochemical sector. This crisis coincided with the rapid expansion of the petrochemical sector in Brazil which at that time used very cheap feedstocks.
In 1970 Cia Brasileira de Estireno closed down its ethylene plant.
In 1971 Union Carbide closed down its ethylene plant too, and Coperbo its butadiene plant.
In 1973 Eletro Cloro also stopped, temporarily, its ethylene unit.

From 1975 onwards

Strong come back, with the creation of the ProAlcool, in which the ethanol-based chemical industry was to play a major role. Although the original planned objectives have not materialized in the short term.

1950s and 1960s; thirdly is the declining phase of the early 1970s, and finally the post 1975 phase in which the alcohol industry expanded at an unprecedented rate and ceased to be a by-product of the sugar industry.[7]

This historical experience is important to understand because it served as the basis upon which the rapid expansion and technological development was built. Despite the difficulties facing this industry, Brazil is in a strong position to develop an alcoholchemistry industry, because: (i) of accumulated experience in this field; (ii) the size of the alcoholchemistry in Brazil is unparalleled in any other country, if one excludes India, which has also been a pioneer in the manufacture of several organic chemicals.[8] No other country has an ethanol-based chemical industry of any significance, a situation on which Brazilian firms try to capitalise.[9]

A further expansion of this industry would appear to be feasible in Brazil, at least in the not too distant future, because of petroleum import savings considerations; less investment requirement; as a way of controlling sugar prices; and because smaller plants are required which is particularly suitable for small markets. An additional advantage is that these plants could be set up near the sugarcane mills to take advantage of sugarcane bagasse surpluses to generate its own energy and lower transport costs.

However, the future of the alcoholchemistry industry must be seen within the context of the petrochemical industry, in Brazil in particular, and worldwide in general. External factors such as oil prices and the new petrochemical plants now coming on-stream, particularly in the Middle East and more specifically in Saudi Arabia,[10] are bound to have profound worldwide impacts for chemical production. A major advantage of Saudi Arabia is the low cost of natural gas - a major chemical building block - which is available to the petrochemical industry at marginal costs. This overproduction and intense competition makes it very difficult to compete with petrochemicals except in certain cases and for specialty chemicals.

A second factor to consider is the petrochemical sector in Brazil itself. It is a modern and still expanding sector, whose installed capacity has increased from 1.15×10^6 tons in 1969, to 8.4×10^6 tons in 1979 and 10.1×10^6 tons in 1983.[11] This represents 42.6% of Latin America's installed capacity and 66.2% of all plastics production.[12] Plastics are important candidates for the alcoholchemistry.

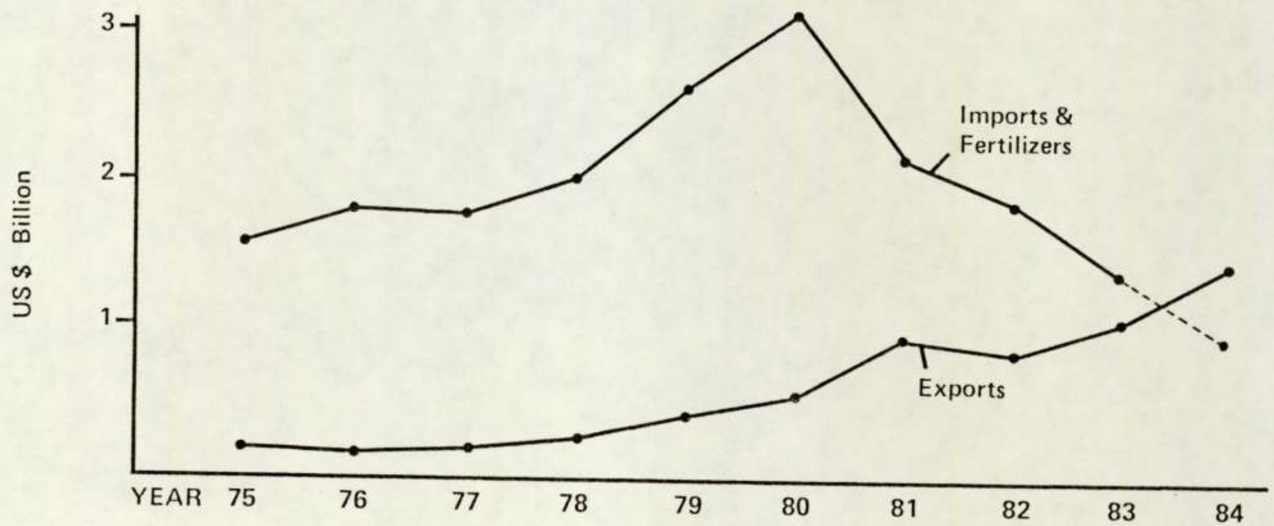
Petrochemicals are also becoming a major source of export earnings, unlike a decade ago when this sector was responsible for large imports, as illustrated in Figure 7.1. In 1975 the chemical sector imports bill was $1.6 billion, and $3 billion in 1980. In 1984, however, there has been an estimated $50 million surplus. A further point to notice is capital ownership. In 1969, 62% of the chemical industry was foreign owned, whilst in 1983 this proportion fell to 25.4%.[13] This has been due to a deliberate government policy to gain control of the petrochemical industry. In this sense this industry would be politically more manageable than, say, the automobile industry.

7.3 Alcoholchemistry: Installed Capacity

The recent expansion of the alcoholchemical industry, after the creation of the ProAlcool, has been determined by the combination of three main factors: (i) technical experience; (ii) economics; (iii) marketing strategy. The main expansion has taken place predominantly in areas of poor industrial development and usually away from the main petrochemical centres. However, this expansion, as shown in Figure 7.2, has been very uneven with high fluctuations. Except for 1981 when there was a sharp decline due to the economic recession, the annual growth has been very high. The fall in 1981 was caused by a fall in demand for chemical products in both the domestic and

Fig. 7.1

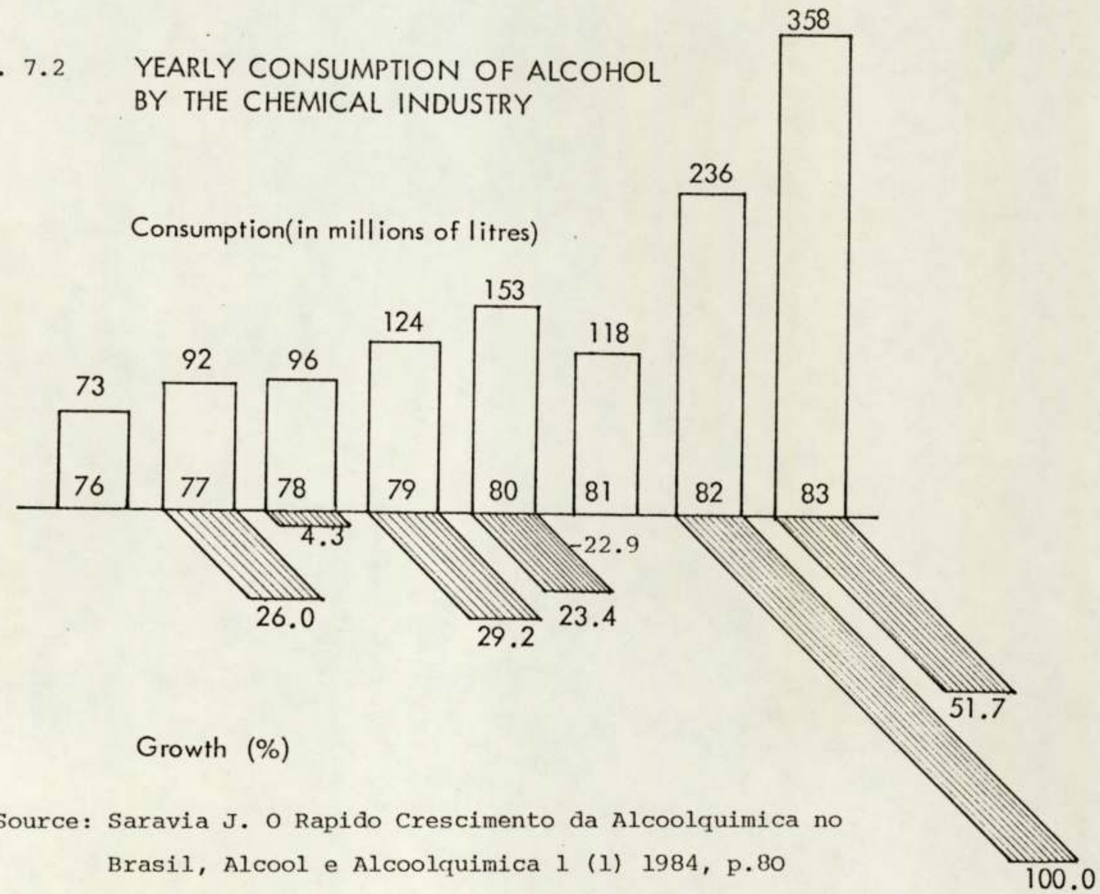
Brazilian Petro-chemical Import and Export 1975–1984.



Source: ABIQUIM

- - - - - - - - - Estimated

Fig. 7.2 YEARLY CONSUMPTION OF ALCOHOL BY THE CHEMICAL INDUSTRY



Source: Saravia J. O Rapido Crescimento da Alcoolquimica no Brasil, Alcool e Alcoolquimica 1 (1) 1984, p.80

international markets.[14] Nonethelesss, despite the rapid expansion of the alcoholchemical industry, it has been well below the 1.5×10^9 litres planned for 1985.

Table 7.2 shows the installed capacity of the alcoholchemistry industry in 1975/76 and 1984. Such capacity increased from 60,105 tons per year with a potential alcohol consumption of 87.5×10^6 litres, to 336,980 tons per year with a potential alcohol consumption of 573.5×10^6 litres.[15] The estimated alcohol consumption for 1985 is 676×10^6 litres and 877×10^6 litres for 1986 and 887×10^6 for 1987.[16] The most important alcoholchemical products are ethylene and acetaldehyde.

The rapid expansion of the past few years, particularly since 1982 and mid 1983, is due to specific measures aimed to stimulate the industry, particularly for exports. There are strong economic reasons to export chemical products rather than alcohol 'in natura', because of the higher added value of the former - approximately $\$344m^3$ as opposed to $\$23m^3$ of alcohol 'in natura'.[17] In 1984 the alcoholchemical industry exported approximately 0.26×10^6 tons of products worth \$89.2m. The most important products were dichloroethane with 67.8% of total; polyethylene with 11.7% and acetaldehyde with 9.5% (see Table 7.3). By company, the first place is occupied by Salgema with 47.3%, followed by Union Carbide with 23.7% and Coperbo with 11.4%.[18] It has been thanks to the exports that this industry has been able to survive and expand at the same time.

Table 7.2 The Ethanol-based Chemical Industry:Installed Capacity 1975-1984.

Company	Product	Installed Capacity (tons/year)		Potential Consumption of Hydrated Alcohol (10^3 litres)	
		1975/76	1984	1975/76	1984
Alba Quimica	Acetic aldehyde	-	7 200	-	11 002
Butilamil	Acetic acid	300	2 880	300	4 781
	Ethyl acetate	250	3 660	413	3 118
Cloroetil	Acetic aldehyde	-	10 200	-	15 586
	Ethyl acetate	-	10 000	-	7 120
Cia Brasileira de Estireno	Ethylene	-	5 000	-	11 450
	Ethyle chloride	-	330	-	634
Coperbo	Acetic aldehyde	-	48 000	-	73 344
Eleikeiroz	Octanol	3 000	13 200	8 136	35 799
	Butanol	145	5 200	288	11 440
	Ethyl acetate	360	1 650	520	2 383
Eletrocloro	Ethylene	10 000	-	22 750	-
Hoechst	Acetic aldehyde	4 200	-	7 350	-
	Ethyl acetate	2 500	-	1 560	-
Imbel	Diethylic ether	-	200	-	367
Oxiteno*	Glycolic esters	8 000	18 000	5 537	12 060
Rhodia	Acetic aldehyde	20 000	52 000	30 560	79 456
	Ethyl acetate	9 000	36 000	6 408	25 632
	Diethylic ether	1 000	1 560	2 338	2 362
Salgema	Ethylene	-	80 000	-	91 600
U.Carbide	Ethylene	-	40 000	-	183 200
Usina Victor Sense	Acetic acid	450	-	630	-
	Butyl acetate	900	1 100	810	990
	Acetic aldehyde	-	800	-	1 222

*Anhydrous alcohol consumption potential in 1975/76= 5 336; for 1984= 11 569.

Source:

Saravia J. O Rápido Crescimento da Alcoolquímica no Brasil Alcool e Alcoolquímica, 1 (1) 1984, p.82.

Table 7.3 Exports of Alcoholchemical Products in 1984 (a)

Product	Tons	%	(10^6)	% increase
Dichloroethane	176,222	67.8	42.2	47.3
Polyethylene	30,350	11.7	21.0	23.6
Acetaldehyde	24,589	9.5	10.2	11.5
Ethyl Acetate	15,778	6.1	7.4	8.4
Glucose	11,333	4.3	7.1	8.0
Other	1,605	0.6	1.0	1.2
Total	259,877	100.0	89.197	100.0

Note: (a) Preliminary estimates.
Source: Cenal Relatorio Anual 1984, Cenal 1985, p.23, Table 25.

7.4 Alcoholchemical Processes

Because this is an area which requires more specialized knowledge and because of the difficulties in gathering data, it is not easy to provide a detailed account of what is actually happening in terms of new developments. Many such new technical developments remain in the companies' private files. There is, I would think, a lack of consensus on the actual state-of-the-art of alcoholchemical processes in Brazil.

It was not until the creation of the ProAlcool that new and improved processes were actually introduced on a much larger scale, and research became a priority in a number of universities and research centres. Nonetheless this does not deny the fact that thanks to Brazil's historical experience, many firms were able to master alcoholchemical processes rapidly enough to take advantage of the new opportunities.

The technology, however, could be regarded as being fundamentally of foreign origin. Most alcoholchemical companies were originally foreign subsidiaries who developed the technology (e.g. the most traditional processes) and transfered it to Brazil through these subsidiaries.[19] For example Rhodia was a subsidiary of Rhone-Poulenc; Cia Brasileira de Estireno, a joint venture between Koppers, Huls and Firestone; Electrocloro a Salvey's subsidiary.

Thus ethylene processes were transfered by Union Carbide, Scientific Design and Koppers through turn-key projects; acetic acid, acetaldehyde, butanol and octanol product processes by Rhone-Paulenc, Union Carbide, Mielle, Hoechst, etc.[20] Although many of these processes were discontinued at one point, there is no doubt that this accumulated experience and know-how formed the basis for the rapid expansion and scale-up of new projects.

Today some experts argue that Brazil not only has the largest alcoholchemistry in terms of installed capacity but also a world leadership, and the capacity to fully develop this industry should the country choose to do so.[21] This, however, has been questioned by some critics, who argue that despite the recent developments, the technology used remains old, inefficient and very much dependent on foreign companies. The country will find it very difficult to compete in the international markets because Brazil lacks the capacity to develop the basic engineering processes. This is in addition to the strong competition the industry has to face from the petrochemical sector.[22]

Generally, one sees the need for large and important changes in the alcoholchemical industry if this industry is to compete with the petrochemical sector, at least technically speaking. Political and economic considerations are, however, of greater importance. But new and direct routes to produce chemical products from alcohol and to scale up are two points in mind.

Table 7.4 summarizes potential technological innovations needed, and which could be obtained in the short term. Firstly, one must notice that the main obstacle is low productivity in the agricultural sector; secondly is the need to reduce energy consumption, particularly steam; and thirdly is the need to increase efficiency in the transformation process of alcohol to final products.

Table 7.4 Potential Short-term Technological Improvements/ Innovations in the Production of Ethanol-based Chemical Products.

Alcohol Distillery

Increase alcohol production to a minimum of 77 litres per ton of sugarcane.
Increase the distillery operation from 180 to 300 day/year.

Ethylene Production Plant

Reduction of alcohol consumption per ton of ethylene from 1.70 tons to 1.68 tons.
Reduction of steam consumption from 2.07 tons per ton of ethylene to 1.43 tons.
Utilization of biogas produced from sugarcane bagasse, instead of other fuels.

Acetaldehyde Production Plant.

Reduce alcohol consumption from 1.16 tons per ton of acetaldehyde, to 1.13 tons.
Utilization of biogas obtained from sugarcane bagasse instead of other fuels.

Acetic Acid Production Plant.

Reduce acetaldehyde consumptiom from 0.78 ton per ton of acetic acid produced to 0.76 ton.

Butanol Production Plant.

Reduce consumption of acetaldehyde from 1.40 tons per ton of butanol produced to 1.36 tons.

Octanol Production Plant.

Reduce alcohol comsumption from 2.22 tons per ton of octanol produced to 1.76 tons.
Utilization of biogas in place of other fuels.

Butadiene Production Plant

Reduce alcohol consumption from 2.44 tons per ton of butadiene produced to 2.13 tons.

Source:

Ribeiro Filho F. Aspectos Técnicos-Económicos e Tecnológicos dos Processos Alcoolquímicos, First Brazilian Congress of Alcoholchemistry 23-26 June 1981, S.P.

All major companies in the alcoholchemical industry have, nonetheless, R&D programmes. This is illustrated on Table 7.5. Most of these processes are still in early stages of development. The main research areas are in the production of ethylene, acetaldehyde, acetic acid and butanol. There is only one plant producing butadéne. By company those with the greatest technological capability include Petrobras, Petroquisa, Oxiteno and Rhodia.

There are also a number of other companies involved in this area of research, such as Petrolex, Congas, Natron, Dow Chemical, etc. and universities such as São Carlos, UFRJ.[23] This research interest is encouraging, although much needs to be done.

Currently only six products are obtained directly from alcohol: ethylene, acetaldehyde, ethyl ether, butadene, ethylamines and ethyl chloride. Ethylene is produced by dehydration of alcohol normally by means of catalysis. Acetaldehyde and its derivatives (acetic acid and solvents) have always been manufactured through the ethanol route, according to Texeira.[24] This consists of the dehydrogenation of ethanol.

As for the possible short term developments in the alcoholchemical processes, one may include the following: (i) production of ethyl benzene directly from ethanol; (ii) use of fluid bed in the production of ethylene; (iii) production of butanol directly from ethanol; (iv) production of ethylene oxide from ethanol directly; (v) autothermal process for the production of acetaldehyde, combining in the same reactor the dehydration and oxidation reaction; (vi) production of acetic acid in gas phases; (vii) production of formaldehyde directly from ethanol.[25]

7.5 Political and Economic Issues

ABIQUIM argues that the fact that most companies in the alcoholchemistry industry are investing in new and improved plants, would be

Table 7.5 Technical Capability of Domestic Firms in Alcoholchemistry Technology

Observations: UD - UNDER DEVELOPMENT; PP - PILOT PLANT; BP - BASIC PROJECTS; OP - OPERATIONAL (industrial plant)

Firm \ Product	Ethylene	Acetic Aldehyde	Acetic Acid	Butanol	Octanol	Butadiene	Ethyl Chloride	Diethyl Ether	Glycoside Ethers
PETROBRAS-CENPES	UD, PP	UD, PP	UD, PP						
PETROQUISA-GETEC			UD, BP						
ELECTRO CLORO	UD, OP								
COPERBO	UD, PP	OP	UD, PP			OP			
OXITENO		UD, BP	UD, BP	UD, BP					UD, BP OP
ELEKEIROZ NE		UD, BP OP		BP, OP UD	UD, BP OP				
RHODIA	BP	UD, PP BP, OP	UD, PP BP, OP	BP, OP	BP		BP	BP, OP	
CBE	UD, BP OP						UD, PP BP		
UNION CARBIDE	UD, OP								
CLOROETIL		UD	UD	UD					
HOECHST		OP	OP						
UNICAMP		UD							
CTP (PROMON)	UD, PP BP								
IPT	UD, PP BP								

Source: ABIQUIM

the best guarantee that this industry has a future.[26] A strong argument in favour of the alcoholchemistry is that is has evolved based on Brazil's natural conditions - e.g. abundant raw materials, technical know-how and long historical experience.

Yet at the same time the expansion of this sector faces an uphill battle. The alcoholchemistry is far from being consolidated; it is too small if one compares it to the petrochemical sector and with low efficiency and high feedstock cost.[27] There is also the question of the new natural gas discoveries in Brazil, which seem to be quite significant. Natural gas can produce ammonia and methanol which are important chemical building blocks, and which is cheaper than ethanol. However these gas discoveries are far away from the main demand centres; and in addition Brazilian demand for natural gas for other uses, e.g. cooking and other industrial uses, is quite large and it is possible that it would not pose a serious threat to the industry.[28]

It is an irony that the creation of the ProAlcool has created new problems for the alcoholchemistry, according to Unger, in two main ways. First because in the pre 1975 era alcohol was a by-product of the sugar industry, which represented a very small proportion of the mill owner's income. It was, usually, a marginal activity. Second, since 1975 alcohol has been increasingly produced in autonomous distilleries, which represent 100% of the distillery's owner income. As a consequence, the price of alcohol increased dramatically and therefore it became necessary to subsidize the alcohol used as a feedstock in the chemical industry.[29]

These subsidies were created by the government decision to produce alcohol in large scale to replace gasoline. Hence the greater the amount of alcohol fuels, the greater would be the gasoline surpluses or the need to produce gasoline (see also 8.2.2). This could create problems because many subsidies come from gasoline.

There exist also the problems of naphtha surpluses. Of the four main industrial uses of naphtha (as raw material in the petroleum industry, blended with gasoline in different proportions, export and blended with alcohol and gasoline) the best alternative is to be used as a chemical feedstock. This is because it offers the greatest economic return. Therefore the fall in demand for gasoline would lead in turn to increasing surpluses of naphtha. These naphtha surpluses could lead to a two-fold increase capacity in the petrochemical sector. In other words, in the short-term at least, the ProAlcool creates naphtha surpluses which in turn increases the competitiveness of the petrochemical sector.[30]

There are also technical problems with alcohol feedstock quality, which is beyond the control of this industry. So far as one can tell, it remains difficult to ensure that all distilleries supply high alcohol quality.[31] Quite often the alcohol has to be further treated to eliminate impurities. The main reason seems to stem from lack of clear specifications on alcohol quality and control. For example for hydrated alcohol fuel, the specifications are the responsibility of the IAA; these are 92.6-93.8^{o}GL. For the chemical industry these specifications are the responsibility of the CNP who establishes a minimum of 93.8GL.

But perhaps the most compelling factor, according to industrialists, is policy inconsistency with the alcoholchemistry which appears full of contradictions. A glance at Table 7.6 shows the frequent and conflicting policy changes. The latest information is that the government is withdrawing the financial incentives to alcoholchemical export products. This policy, according to ABIQUIM will put at risk a number of projects already on-stream or planned, worth hundreds of millions of dollars.[32]

Thus the expansion and consolidation of this industry do not depend on new improvements <u>per se</u> but would depend very much too on government

Table 7.6 Political Evolution of the Ethanol-based Chemical Industry Since 1975.

Decree No.76 593 of 14 November 1975

Established a subsidy to the alcohol used in the chemical industry, when used to replace imported chemical products. This subsidy was set at a maximum of 35% the price of one Kg. of ethylene. It also established that resources accruing from the sale of alcohol fuels would preferably be used to support the chemical industry.

Decree No. 80 762 of 18 November 1977

Further consolidated de ProAlcool and more specifically the alcoholchemical industry.

Decree No. 83 700 of 5 June 1979

Fixed the price of alcohol used as chemical feedstock, to be the equivalent of one litre of alcohol 100% by weight, and based on 35% of the price of one Kg. of ethylene.

Decree No. 1 686 of 26 June 1979

Reduced taxes on chemical products in general, including derivatives of ethanol (eg.ethylene, acetaldehyde, octanol,etc)

Act No. 17/80 of 30 October 1980

Guaranteed the supply of hydrated alcohol to the chemical industry

Act No. 02/82 of 6 January 1982 of the IAA

Established a tax of 5% and 11% on the alcohol used on alternative and non-alternative chemical routes.

Decree Law No. 87 813 of 16 November 1982

Established alcohol subsidies 100% the price FOB of one litre of naphtha for the alternative chemical routes and 170% for the non-alternative chemical routes. It created new difficulties for exports.

Act No. 34/83 of 8 August 1983 of the IAA

Eliminated payment of alcohol taxes to the IAA when alcohol is used as a chemical feedstock for exports

(Table 7.6 cont.)

Act No. 09/83 of 9 August 1983 of the CNP

Established new conditions for the utilization of alcohol as a chemical feedstock.
In February 1985 the CNP withdrew the financial incentives (backdated to November 1984) for alcoholchemistry-based export products. This has created, according to Abiquim, new problems for alcoholchemistry because this industry will be unable to compete in many cases.

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Source:

Compiled from different sources, mainly from Sanefuji T, Alcoolquímica no Contexto da Indústria Química Brasileira, Second Brazilian Congress of Alcoholchemistry, 19-23 September 1983, Refice.

policy. With reference to the cost of producing alcoholchemical products, it is a complex and difficult issue because subsidies, taxes, hidden costs, etc. (see table 7.6 and Section 8.2.2). However the price of alcohol is the most important variable in a strict economic sense, in determining the competitiveness of ethylene and its derivatives.[33] Table 7.7 compares alcoholchemical with petrochemical products. These prices include susbidies and should be seen as tentative estimates. It is worth remembering that petroleum products are also subsidized.

Table 7.7 Estimated Prices for Alcoholchemical and Petrochemical Routes

	Price $ per ton (16 August 1983)	
Product	Alcoholchemistry	Petrochemical
Ethylene	442	436
Acetaldehyde	585	641
Acetic Acid	686	729
Butanol	829	964
Octanol	1428	1288
Butadiene	1360	591

Source: Sanefuji T, Alcoolquímica no Conexto da Indústria Química Brasileira; 2nd Brazilian Congress of Alcoholchemistry, SP. 20 September 1983. p.28, table 4.

According to this table the production of ethylene can be regarded as feasible when produced from ethanol, whilst acetaldehyde, acetic acid and butanol present substantial advantages when produced through alcoholchemical routes. Butadiene and octanol are economically unfeasible when produced from alcohol.

7.6 Specialty Chemicals: Sucrochemistry

Considering the difficulties facing the ethanol based chemical industry in

Brazil, in spite of its natural advantages, some industrialists have argued in favour of specialty chemicals. This is an area where the non-petrochemical sector could expand rapidly without facing intense competition. The debate about 'fine chemicals' in Brazil has been so intense that Unger rightly once stated: 'in the past four years specialty chemicals have produced more symposiums than products.'[34] However, this is an area of great importance for the chemical industry as a whole and where a number of major chemical firms are planning their expansion strategy.[35] In the case of Brazil, the MNCs controlled 77% of the specialty chemicals - some $3.5 billion of total sales in 1984. Approximately 7500 products can be classified as 'fine chemicals' but 3% of these products represent 50% of the Brazilian market.[36]

There are a large number of fine chemicals which can be produced from ethanol-chemistry. Among these are aluminium acetate used as an additive in the pharmaceutical and food industries; diethyl hexyl peroxydicarbonate used as a plastic additive; piperolene butoxyde used for insecticides; amylacetate and benzyl acetate used in synthetic essence.[37] However, the most promising alternative, at least in the medium and long terms, for specialty chemicals is to expand the present sucrochemistry industry.[38] Some experts believe that Brazil could implement in the near future a large sucrochemistry industry, capable of manufacturing at least 50 of the 10,000 products which can be obtained from molasses and sugarcane juice.[39] Brazil has already a significant industrial base, as can be seen from Table 7.8. The most important products are oxalic acid, citric acid, lactic acid, sodium gluconate, sorbitol, mannitol, fatty acids, acetone and vitamins.

According to Promon, the following fine chemicals could be produced in the short term: the family of organic acids; fine alcohols; antibiotics; biopolymers; cell derivatives; fatty acids of sucrose, vitamins (B2 and B12) and plastics.[40]

Table 7.8 The Sucrochemistry Industry in Brazil: Installed Capacity in 1981.

Product	Company	Installed Capacity(ton/year)
Oxalic acid	Explo-IndustriasQuimicas e Explosivos S.A.	5 400
Ammonium oxalate	Usina Colombina S.A.	80
Citric acid	Fermenta-Prod.Quimicos Amalia	5 000
Ibid	Agroquisa S.A.	12 000*
Sodium citrate	J T Baker-Prod.Quimicos S.A.	ND
Ibid	Proquinter-Ind.Com.Prod.Quim.Ltda	ND
Ferrous calcium citrate	Johnson&Johnson	60
Ibid	J T Baker-Prod.Quimicos S.A.	165
Ferrous ammonium citrate	Dyne Prod.Quim.Ind.e Com. Ltda	125
	Croquimica Ltda.	
	Macks Prod.Quim.Farm. Ltda.	
Lactic acid	Ind.Quim.Sinteses Ferment. S.A.	1 800
Calcium gluconate	Ind.Quim.Resende S.A.;Sandoz S.A.	80
Calcium/sodium etc.	Ind.Quim.Sintesis e Fermentacoes S.A.	700
Gluconic acid	Pfizer Quimica S.A.	400
Calcium gluconate	Ind.Quim.Resende S.A.	68
Ibid	Lab.Beecham	60
Ferreus gluconate	Ind.Quimica Resende S.A.	
Ibid	Sandoz S.A	75
Ibid	Dyne-Prod.Quim.Ind.Com.Ltda	24
Calcium gluconate	Sandoz S.A.	15
Ibid	Ind.Quim Resende S.A.	
Sodium gluconate	Pfizer Quimica S.A.	10 000
Ibid	Glucon Quimica S.A.	720
Magnesium gluconate	Sandoz S.A.	32
Butanol	Usina Victor Sence	2 400
Sorbitol	Getec-Guanabara Quim.Indust.S.A	12 000**
Mannitol	Ibid	1 200**
Sorbitol of fatty acids	Atlas Industrias Quimicas S.A.	4 000
Ibid	Etoxildos do Nordeste S.A.	
Fatty acid esters of saccharose	Sacarose Quimica S.A.	3 000*
Monosidium gluconate	A J Inomoto Interamec.Ind.Com.SA	13 000**
Ibid	Oriento	3 360
Acetone	Usina Victor Sence S.A.	1 300
Vitamim C	Alagoas Materias Primas Farm. S.A.	1 500*

(Table 7.8 cont.)

Penicilin G	Fontoura Wyeth-Ind.Farm. S.A.	168
Ibid	Squibb Ind.Quimica S.A.	195
Others	Atlas Ind.Quimicas S.A.	360
	Bayer do Brasil S.A.	
	Propenasa-Prod.Petroquim.Nac. S.A.	1 500

Notes: * Under study in 1981
** Expansion planned in 1981
ND No Disponible.

Source:
Alcoolquímica 1 (12) December 1983, p.68.

Nonetheless, there are serious problems with this industry because it is very specialized and the know-how is controlled by a handful of companies, particularly Japanese which are the pioneers in this field; and also by Americans.[41] In addition there is the problem of the small market, albeit expanding, for fine chemicals. Thus the expansion of this industry which is potentially very large in Brazil, would demand significant advances in biochemistry, microbiology, genetic engineering, etc. This would probably mean a high presence of foreign capital and know-how. If such expansion of the sucrochemistry industry was to take place, it would represent a remarkable step forward technically speaking and would create many opportunities; at the same time it would take some pressure off the other chemical sectors. After all, if Japan can produce fine chemicals from Brazilian molasses, why could not Brazil who produced them?

7.7 Perspectives

Thus, what are the real perspectives for the expansion of the ethanol-based chemical sector? The outcome seems to depend very much on political rather than economic factors, although economic considerations are, of course, very important. Technically, the Brazilian firms do appear to have the capability to develop their industry, including new direct routes to produce chemicals from alcohol directly. This last point is, of course, a more contentious issue.

World markets situation would be an important influencing factor, if one considers that Brazilians are increasingly looking to foreign markets to place their products. Considering that important petrochemical plants are coming on stream, competition would be more severe. An encouraging sign, however, is that international trade of chemicals is expected to increase by 5% annually, particularly in Third World markets,[42] and that the Brazilian market is also expected to grow considerably.

The ethanol-based chemical industry, unlike the petrochemical sector, presents Brazil with a unique opportunity, due to the combination of a number of factors: (i) large market and with great potential for expansion despite the large petrochemical sector; (ii) abundant raw materials, which are renewable, domestically produced and with great scope for real cost reduction; (iii) a strong technological base and historical experience on which to build.

If one considers also the capital investment committed over the past few years, together with the numerous options that the alcohol industry offers, then this industry seems to have a secure place in Brazil. There is also a potential Third World market, not only for alcohol-chemical products but also for technological exports. This is because the alcohol chemical industry is less capital intensive and is very suitable for small markets. There are also a number of countries which cannot produce ethylene (the main organic chemical building block) because of lack of or non-availability of chemical feedstocks, e.g. naphtha or natural gas. The transfer of alcohol technology to other countries appears to be a workable alternative. The actual diffusion to other economies will depend on a number of factors, e.g. the ability to put together technological and financial packages.

With regard to the domestic market some industrialists have suggested that the aims of the alcoholchemistry should be: (i) to supplement rather than compete with the petrochemical industry. That is, it should manufacture those products which cannot be made, or are more expensive to produce by the petrochemical route; (ii) to attend to regional demand of basic products outside the influence of the petrochemical centres, e.g. the North East); (iii) to expand in areas of low demand for chemical products but large producers of alcohol. Future plants should be set up near the distilleries of alcohol to take advantage of the energy surplus.[43]

Generally speaking then, the future expansion and consolidation of the non-petrochemical industry appears to be strictly linked to: (i) guaranteed supply of raw materials, e.g. alcohol; (ii) optimization of the industry as a whole; (iii) a clearer policy on both the petrochemical and the ethanol-based chemical industry. If the alcoholchemical industry was to expand, it would create the conditions for a technological autonomy in this industry.

CHAPTER 8

SOCIOECONOMIC AND POLITICAL ISSUES

Introduction

In this chapter I do not pretend to present a comprehensive view of the socioeconomic and political problems posed by the ProAlcool. Such study is beyond the stated objectives of this thesis. Rather I would highlight the main criticisms of the ProAlcool. The success or failure of the programme is of great interest for those who are concerned with finding new development and energy alternatives.

In this chapter I will consider some of the current political issues; production cost of ethanol; price policy and energy balance; environmental impacts; food versus fuel controversy; net employment and main constraints and criticisms.

8.1 General Political Considerations

The political and economic crisis of Brazil is well known. The country has gone through the most severe and difficult economic crisis in living memory. A crisis which has led to an erosion of national self-confidence and disillusionment. The middle classes who in the past 20 years made the most gains has seen them almost virtually wiped out. Meanwhile, for those at the bottom of the national league, deprivation has risen to levels unseen this century.

The soldiers took over in 1964 to end galloping inflation and corruption. After two decades, they have left the country with the same sickness, but in a far worse state; and with the world's largest foreign debt. Unable to contain the deepening economic crisis, discredited by the economic failure and unaccounted scandals, the military finally decided to abandon the "Planalto".[1]

However, no one can deny that the country has not seen important changes. In the past 20 years the country has fulfilled many of its ambitions. It has become the world's eighth-ranked economic power, with an infrastructure and industrial base greater than many industrial nations. But its cities are still made up of palatial mansions and filthy shanty towns; its social structure displays the widest gulf between rich and poor recorded in any nation.[2]

If the economic recession was not bad enough, the country has gone through a period of political paralysis. Firstly with the battle for and against direct presidential elections[3]; secondly, by the drama caused by the illness of President-elect Tancredo Neves and his eventual death. For weeks the country came to a standstill, until the Vice-President Jose Sarney finally was formally declared President.[4]

The experience has been traumatic. Tancredo's death has left an enormous vacuum and a climax of great uncertainty, suspicious and functioning mood. The new democratic government represents an enormous popular expectations for economic reform and an end to the austerity of recent debt-ridden years. After the first 100 days of Sarney's government the sense of drift and uncertainty continue as such hopes have vanished, in the absence of any discernible alternative strategy. Sarney wants to introduce reforms. These reforms are difficult to pass by a basically conservative Congress, the political base of landowners and industrialists.[5]

In the economic front, the civilian government has made some achievements. Price controls have helped to bring inflation down to 225% (June 1985), against an expected 400%, and GDP is expected to grow by 5%. But domestic savings are already inadequate to serve fully the debt. Brazil will find it also impossible to continue transferring abroad year after year 4 to 5% of its GDP. The interest bill in 1985 is $14.9 billion - 7% of the GDP; its foreign debt is $104 billion.[6]

Exports remain the best hope - these are expected to top $11.5 billion in 1985.[7] However the combination of a strong dollar to which the "cruzeiro" is linked, and the holding up of subsidized export finance as part of a drive to control money supply, has created new difficulties. The government is resisting pressure from the IMF to cut public expenditure, which will risk putting back the the country on a recession path again. The switch away from the infrastructure and industrial emphasis of the military regime in favour of social expenditure is going to be the hallmark of the Sarney government, according to officials.[8]

But Brazil is a rich country who has gone through difficult times before. Its economic history consists of record breaking booms and short sharp busts. Given time and political will to carry out important political and economic reforms, the country should be able to overcome the present difficulties, at least in the medium and long terms, if one considers Brazil's enormous natural resources.

8.2 Ethanol Production Costs

Ethanol production from sugarcane has been the subject of many studies. Four important cost-benefit studies have been carried out by CENAL, the World Bank, Copersucar and Homen de Melo and Pelin.[9] Their findings differ considerably because of the different methodology used. The first two agree that the ProAlcool is economically viable; the third one suggests that in the medium term the programme will become viable; the last one concludes that such a possibility is very remote. Cost estimates vary from $35 to $90, or even $120 per barrel of gasoline replacement. It is worth recalling once more, that in assessing the cost of producing ethanol, political and social considerations play a significant part.

8.2.1 Investment Cost

Estimates on the total investment of the ProAlcool vary considerably.

According to CENAL the production of 39.1×10^9 litres of alcohol from 1975 to 1984, saved the country $7.3 billion ($1.77 billion in 1984 alone).[10] This value is based on the cost of imported oil; the cost of producing gasoline (refining costs). It also considers differences in calorific value of gasoline and alcohol. However these estimates exclude the benefits emanating from the need to produce less gasoline; the greater flexibility in the refining process which permits changes in the cracking system, to allow greater diesel oil production from a barrel of oil: It also excludes a reduction of imported oil accruing from the greater production of diesel oil.

Geller estimates that to produce 10.7×10^9 litres of alcohol in 1985/86 harvest would require a total investment of $4.7 to $5.7 billion or $6.9 to $8.3 billion if land costs are included. This represents an investment of $0.69 to $0.83 litres of alcohol per year.[11] One should compare it with capital investment for domestic oil exploration, and production in Brazil. In 1982 the cumulative investment cost was $0.29 per litre added to reserves. In 1982 alone the capital investment in domestic petroleum exploration and production was approximately $2.8 billion, which added to oil reserves at a cost of $0.052 litre (in corrected 1982 dollars), according to Geller. Assuming an average production period of 15 years, the investment requirement for oil production capacity is $0.43 litre per year and $0.78, litre per year, in the cummulative and marginal cases respectively. If refining investment costs of $0.07 litre per year are included, then the overall investment costs for domestic oil production are $0.50 and $0.85 litre per year respectively. Thus, on a gasoline replacement basis, the investment requirement for alcohol production becomes $0.56 - 0.68 litre per year (or $0.83 - 1.00 litres per year including land). Therefore ethanol production appears to be about as capital intensive as marginal petroleum production on a replacement basis.[12] These costs appear to exclude tax incentives given to oil exploration (e.g. Petrobra's does not pay any import tax on many of its equipment imports).

Table 8.1 presents a breakdown of costs between gasoline and alcohol. Accordingly, gasoline derived from $29 barrel of imported oil is estimated to cost about $41 barrel ex-refinery in Brazil - $2 shipping cost, plus $10 refining costs. If financial charges are normally included in the cost of alcohol, it is consistent to do the same for gasoline from imported petroleum.

According to Geller, during 1974-1982 Brazil paid 12.2% average nominal interest rates on its foreign loans. Using inflation rates in the USA. to correct the nominal interest rates (this was 4.2% per year), a $29 barrel oil ends up costing $40.3 per barrel, if the interest changes are fully capitalized for eight years. Thus, the ex-refinery cost becomes $52 barrel (excluding interest charges that occur as the loans are ultimately paid back). Since normal interest payments are over 10 years, it would lead to a 25% overall increase in the cost of imported oil in real terms, or $48 per barrel. But considering that interest rates on foreign loans were in 1983, c.8% per annum, the financial imported crude oil (using a ten years loan at 8% interest) end up costing $55+ barrel of gasoline derived from imported oil in 1983, excluding capitalization of interest rates.[13]

The quoted CENAL study estimates for S.P. were between $41 - 54 per barrel of gasoline replaced (in mid 1983 dollars).[14] The study also uses the USA inflation rates as a basis for monetary correction from 1980-83. It should also be noted that these costs are much higher in the North-East. The CENAL study was based mostly in the Centre-South region.

The Copersucar study, also based on production costs in S.P. and surrounding areas, uses a higher average cost because its policy is to obtain higher prices from the government. This is to ensure economic viability for the large majority of the production units and to maximize their profits. The profit margin for capital investment is 12%, but excludes financial subsidies provided by government. These estimates could be viewed as an approximation of the true unsubsidized production costs without profits.

Table 8.1 Overall Cost Comparison Between Ethanol and Gasoline*

Parameter	Value
Ethanol	
Sugarcane cost	$10-12/ton
Ethanol yield	65 litres/ton
Distillation	$0.9-011/litre
Ethanol production cost	$0.264-0.295/litre
Replacement ratio for - full gasoline replacement	1.2 litres (hydrated alcohol) per litre of gasoline.
Replacement ratio for -20% ethanol,80% gasoline blend	1.0 litre (hydrous alcohol) per litre of gasoline.
Ethanol cost,full gasoline replacement	$50-56 per barrel of gasoline replaced.
Ethanol cost, 20% ethanol 80% gasoline blend	$42-47 per barrel of gasoline replaced.
Gasoline	
Imported petroleum (including transport)	$31 per barrel
Import surcharge (20%)	$6 per barrel
Refining cost of gasoline	$10 per barrel
Total gasoline cost	$47 per barrel.

Source:

Geller H. Ethanol From Sugarcane in Brazil, Ann. Review of Energy, Vol.10, 1985(in press).

* Costs in 1983 $ assuming gasoline is derived from imported petroleum.

Table 8.2 shows the cost breakdown according to the Copersucar analysis. The production cost is c.$0.28 - 0.33 per litre of anhydrous alcohol - or $49 - 59 barrel of gasoline replacement. Agricultural costs represent 64.4% and industrial costs, 35.6%.[15]

Borges estimates that production costs have been declining by 4% annually, reflecting greater efficiency. He estimates that a further 20% reduction cost can be achieved in the medium term, in both agricultural and industrial phases.[16] These improvements refer to production costs only. Improvements in end-use of alcohol are also very important. For engine improvements of ethanol-fuelled cars, have resulted in significant fuel consumption cuts; and a further 20% could be achieved in the short term. These possible improvements are often ignored by critics who base their estimates on present technology. Over $45 per barrel, ethanol from sugarcane would be viable in all cases, at least in S.P. according to Borges.[17]

Homen de Melo has been one of the most outspoken critics of the ProAlcool. He regards the programme as uneconomic and wasteful, because there were/are cheaper alternatives than producing alcohol. His estimates are as follows: Coal $10 - 15; charcoal $19 - 24; shale oil $30 - 40; gasified coal $41 - 69; domestic oil $15 - 20; hydrated alcohol as gasoline substitute $79 - 91; hydrated alcohol as diesel oil substitute $137 - 158; additivated alcohol (alcohol + additive) $148 - 170; vegetable oils as diesel substitutes $84 - 140.[18]

These figures are very questionable. Homen de Melo does not say how he arrives at these estimates. He does not provide sufficient evidence either to support these findings and appears to oversimplify and underestimate a number of important factors. Let us take coal, for example. Brazilian coal contains a very high sulphur content; and generally this poor quality means higher cost and poor efficiency. Another example is the cost of domestic oil. These figures seem to be too low and do not consider the full cost of producing domestic oil, as considered by Geller.

Table 8.2 Estimated Alcohol Production Costs in São Paulo State*

Component	Production Cost Cr$/litre**	Production Cost US$/litre***	Percentage
Agricultural			
-operating	36.3	.118-.142	42.5
-capital	8.9	.029-.035	10.5
-land	9.7	.032-.038	11.4
Subtotal	55.0	.0179-.215	64.4
Industrial			
-operating	18.8	.061-.073	22.0
-capital	11.6	.038-.46	13.6
Subtotal	30.4	.099-.119	35.6
Total	85.4	.278-.334	100.0

Source:

Quoted by Geller H. Ethanol from Sugarcane in Brazil, Ann. Review of Energy Vol. 10, 1985 (in press).

* Costs apply to 1982-83 as estimated by Copersucar.

** Cruzeiro costs apply to September 1982.

*** The official exchange rate in September, 1982 is increased by a factor of 1.25 to 1.5 to account for the overvaluation of the cruzeiro at that time.

Other alternatives such as charcoal will make an enormous demand of forests, and has limited industrial uses although it is a major energy source in the steel-making industry.[19] Shale oil continues to be expensive, and there are many technical problems to overcome. Above all he does not seem to realize that the main problem was not lack of energy sources, but lack of liquid fuels. Vehicle engines do not run, as yet, on coal or charcoal. Ethanol from sugarcane was in the short term the best available alternative, which is not fully recognized by Homen de Melo. In addition Homen de Melo fails to take fully into account in his analysis the overvaluation of the "Cruzeiro" in the past; and also production cost assumptions are in excess of official prices. Albeit in his latest estimates production costs are much lower - $79.42 and $66.70 b.p.e. (January 1983) without and with technical improvements respectively.[20]

Motta also argues that the ProAlcool is not an economically viable alternative. His estimated production costs for alcohol production are $44.92 to $58.04 b.p.e. in S.P.; $64.04 to $82.04 in GO, and $65.99 to $87.65 in PE. But production costs could be reduced by as much as 17.7% in SP; 27.5% in GO and 12.7% in PE in the near future.[21] According to these estimates ethanol would not become economically viable until 1991 in SP, and between 1995 to 2000 in GO.

Motta's calculations are based on the World Bank price estimates for oil[22] which appear to be rather low. He also seems to fail to consider the whole implication of the overvaluation of the dollar, which has resulted in a sharp cost increase of oil import for many developing countries.

It is not uncommon also to hear the argument that the country would have benefited more if the investment put into the ProAlcool, had gone to other alternatives, e.g. commodity exports, which also appear morally more acceptable. Such an argument tends to overlook a number of factors. First commodity exports are subjected to sharp price fluctuations; and have expanded at the expense of traditional crops. Secondly such exports are often for animal feed (e.g. soya bean) and generate less employment because they are produced by more modern methods. Thirdly, this argument does not seem to give full credit for the domestically produced fuel.[23]

8.2.2 Fuel Price Policy

Brazil has a centralized and sophisticated price policy of petroleum-derivatives which corresponds to broader social economic, energy and fiscal policy objectives. Therefore fuel price policy should be examined within the overall national socioeconomic policy. Fuel price policy is thus a complex issue in Brazil, because it is used as an instrument to subsidize many petroleum-derivates (e.g. LPG and diesel oil), and industries (e.g. chemical industries). Because oil refining is a continuous process, it is very difficult to determine the real costs of each petroleum derivative. The official criterium for establishing petroleum derivative prices is based on: (i) exchange rate at the time; (ii) cost of raw materials (in dollars); (iii) processing costs; (iv) taxes on derivatives; (v) margins (refining, resale, distribution).[24]

The major costs of oil increases have been added to gasoline, in order to alleviate the cost of other derivatives, particularly diesel oil, and LPG for cooking. This policy is well illustrated on Table 8.3. For LPG whose price in 1973 corresponded to 81% of gasoline, went down to 26% in 1983; and diesel oil from 76% to 62% over the same period.

For each litre of gasoline sold in the petrol station (in May 1985), 39% (Cr$847) went to subsidize other petrol derivatives and industrial sectors.[25] The transportation system receives billions dollar on subsidies.[26] At the same time, anhydrous alcohol is also used to subsidize gasoline, because it is bought by Petrobras at 65% the price of gasoline (December 1984) but sold as gasoline price at the petrol stations. In this way, according to Biagi[27] anhydrous alcohol generates about $700 m annually on revenue to the State. This, according to the alcohol industrialists, more than compensates for the subsidies received by the alcohol producers. Albeit their figure might cast some doubts, it is nonetheless

Table 8.3 Petroleum Derivatives: Prices to the Consumer from 1973 to 1983.

Product	31 December 1973 Cr$/litre	Index	31 May 1983 Cr$/litre	Index	1983/1973 %
Gasoline	0.89	100	210.00	100	23.44
Diesel oil	0.67	76	130.00	62	19.15
Fuel oil (ATE)	0.16	12	60.39	29	37.55
Fuel oil(BTE)	0.16	19	71.10	34	42.04
Kerosene oil	0.75	85	132.00	63	17.36
LPG	0.71	81	55.24	26	7.59
Average price	0.59	67	125.33	60	20.59

Note: The average price increase of oil imports CIF in Cr$ during the same period was 42 382%.

Source: Almeida Lima O., Política de Preços de Petróleo e Derivados, Atualidades do CNP, 15 (83) July/August 1983, p. 6, table 11.

illustrative of the situation. Critics who see the ProAlcool basically as a subsidy to the middle classes, should do so, in the light of all government subsidies; particularly to diesel oil (mostly for heavy and public transport use) and LPG, used by the majority of Brazilian households for cooking.[28] A further criticism is directed against gasoline surplus, as the result of the PNA; but it is also due to price policy, lower gasoline demand due to better engine performance, and changes in the refining capacity. The government decided to adapt the new refining capacity taking in consideration the growing demand for diesel oil and LPG. These changes also allow to import poorer quality oil (e.g. heavy oil) which is also cheaper, and export gasoline surpluses with an economic advantage.[29]

However, a more realistic fuel price policy is emerging passing more of the market price cost on to the consumer. With the intention of reducing demand, particularly diesel oil. This would result in an increasing demand for coal in many industries now using diesel fuel, or gas oil. At the same time the price of alcohol has been brought more in line with diesel prices (from 87.3% the equivalent price of diesel in November 1983, to 93.3% on 28 December 1984).[30]

With regard to alcohol price policy, it seems that a guaranteed market has discouraged competition and caused economic inefficiency. A better alternative could be to pay the subsidies per each litre of alcohol produced. This would encourage productivity and would penalize the less efficient ones. Secondly, would be regionalization of alcohol prices, so as to reflect more directly real costs. This measure would be particularly significant in the North-East where government subsidies have served to further consolidate the economic power of the traditional sugarcane oligarchy, who has shown little concern for economic efficiency.[31]

8.2.3 The Energy Balance

The energy balance for alcohol production from energy crops, has been the object of controversies. There remain still some doubt, despite a number of studies carried out.[32] With regard to Brazil, in the case of ethanol from sugarcane, a number of studies carried out all have shown to be highly positive.[33] In the case of Cassava or sorghum, the energy balance seems to be less positive; but it is sugarcane what really matters.

The results of the most recent study are shown on table 8.4. It is based on data from 70 distilleries in the SP state, responsible for 40% of alcohol production in Brazil, controlled by Copersucar. Scenario 1 represents the average energy inputs per ton of sugarcane (all items: fuels, transport, fertilizers, herbicides, equipment, labour etc). Scenario 2 considers the best results obtained by optimising the use of the most advanced existing technology; but excludes new technologies under development or existing technologies not widely used. As can be observed the energy balance is very positive, by a ratio of 6.4 and 9.5 for the scenarios one and two respectively. However, the average productivity of 73 and 83 litre of alcohol per ton of sugarcane for scenario one and two respectively, is rather high, and does not represent national average (see table 5.2).

8.3 Environmental Impacts

As noted in 5.6 the environmental implications of the ProAlcool have been a major source of criticism and remain a serious preoccupation. No one could deny the problems posed by the huge volume of stillage, made worse by the lack of environmental awareness that tends to exist in most developing countries. And it is within this context that the "stillage problem" should be analyzed. There has been a general tendency to see this problem in isolation without considering other heavy polluting industries, e.g. the chemical sector.

The environmental impacts caused by the ProAlcool need to be examined under four main headings: (i) environmental problems caused by the production of alcohol - e.g. stillage; (ii) those environmental problems created by alcohol consumption; (iii) environmental quality improvement due to reduced gasoline consumption (e.g. 100% alcohol-fuelled cars); (iv) the induced decrease in

Table 8.4 Energy Balance of Alcohol from Sugarcane.

	Scenario 1		Scenario 2	
	Energy		Energy	
	Inputs	Outputs	Inputs	Outputs
	(Kcal.ton/sugarcane)		(Kcal.ton/sugarcane)	
Agricul.phase	53 050	-	47 240	-
Indust. phase	16 770	-	9 710	-
-Alcohol*	-	408 400	-	464 300
-Bagasse	-	41 900	-	78 600
Total	69 820	450 300	56 950	542 900
Output/Input ratio (positive)	6.4		9.5	

* Scenario 1: one ton of sugarcane= 73 litres of alcohol;
  Scenario 2 one ton of sugarcane= 83 litres of alcohol.

Source: Macedo I C. Horta Nogueira LA, Balanço de Energia na Produção de Cana de Azucar e Alcool no Estado de São Paulo, June 1985. (Copersucar, internal document) pollution generated by oil refineries (e.g. low gasoline production).

It is often the case that the pollution potential of the PNA is considered under the first two headings only. I shall examine item (iii) only, the first two are widely known[34] and the last one because much data is still needed, and it seems less important from a pollution viewpoint.

The effectiveness of alcohol fuels in reducing emissions, have been confirmed by a number of studies.[35] In Brazil considerable efforts have been made to study such implications, particularly by government institutions, with significant results.[36] Results on emissions on vehicles, obtained recently by CETESB (an environmental agency in SP), are summarized in Fig. 8.1. These results have been obtained after eight years of research and a good deal of opposition from the industries affected.[37] As can be observed only in the case of aldehydes, does alcohol increase pollution. However in the case of CO and HC, the most serious pollutants, emissions are much lower.

However, estimates vary because the difference in methodologies. Yeganiantz et. al. estimates are: 65% decrease in CO and 69% in HC, while there is an increase of 13% in NO_x and 441% in aldehydes. For the 20/80% alcohol gasoline vehicles, their estimates are 36% decrease in CO and 24% in HC, and an increase of 24% in NO_x and 112% in aldehydes.[38]

Despite these differences, it is generally well accepted that the alcohol has a positive influence in reducing car pollution. This is demonstrated in Fig 8.2 which shows one-fourth reduction of lead concentration in the atmosphere, from 1978 to 1983 in Sao Caetano and Pinheiros, S.P., two of the most heavily polluted centres in Brazil. This positive influence is expected to increase in the near future as more cars are fuelled by alcohol.[39]

8.4 Food Versus Fuel

This is one of the most heatedly debated issues within and outside Brazil; and one which has received much attention. To most people fuel from crops has a

Fig. 8.1

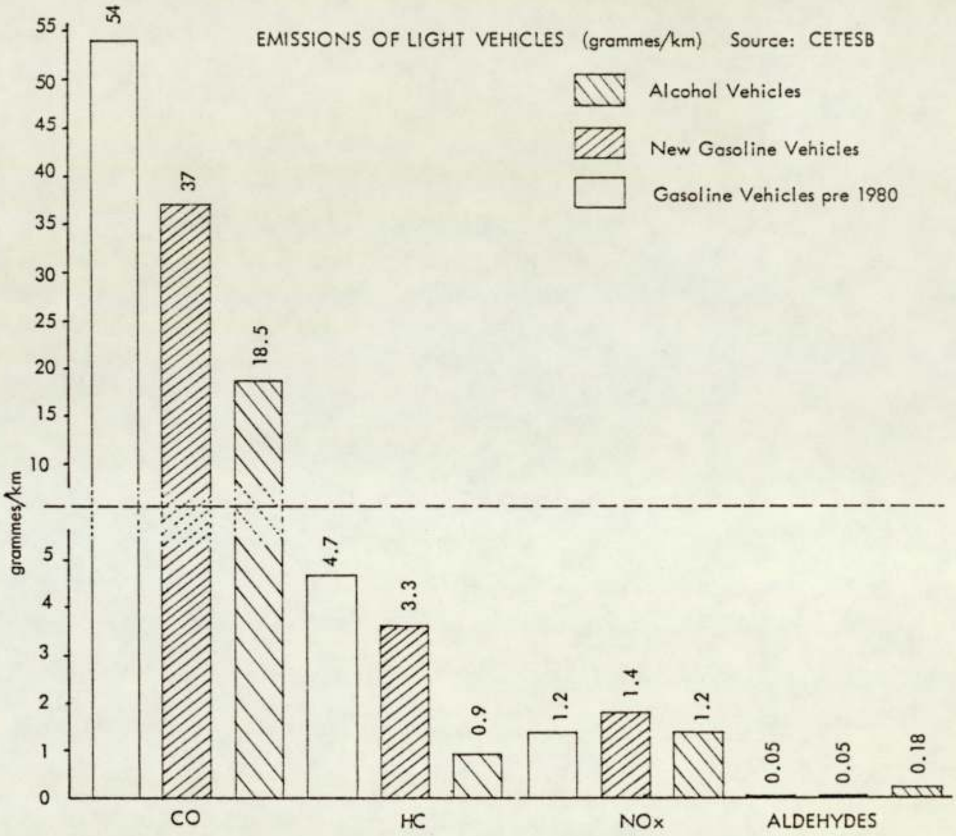
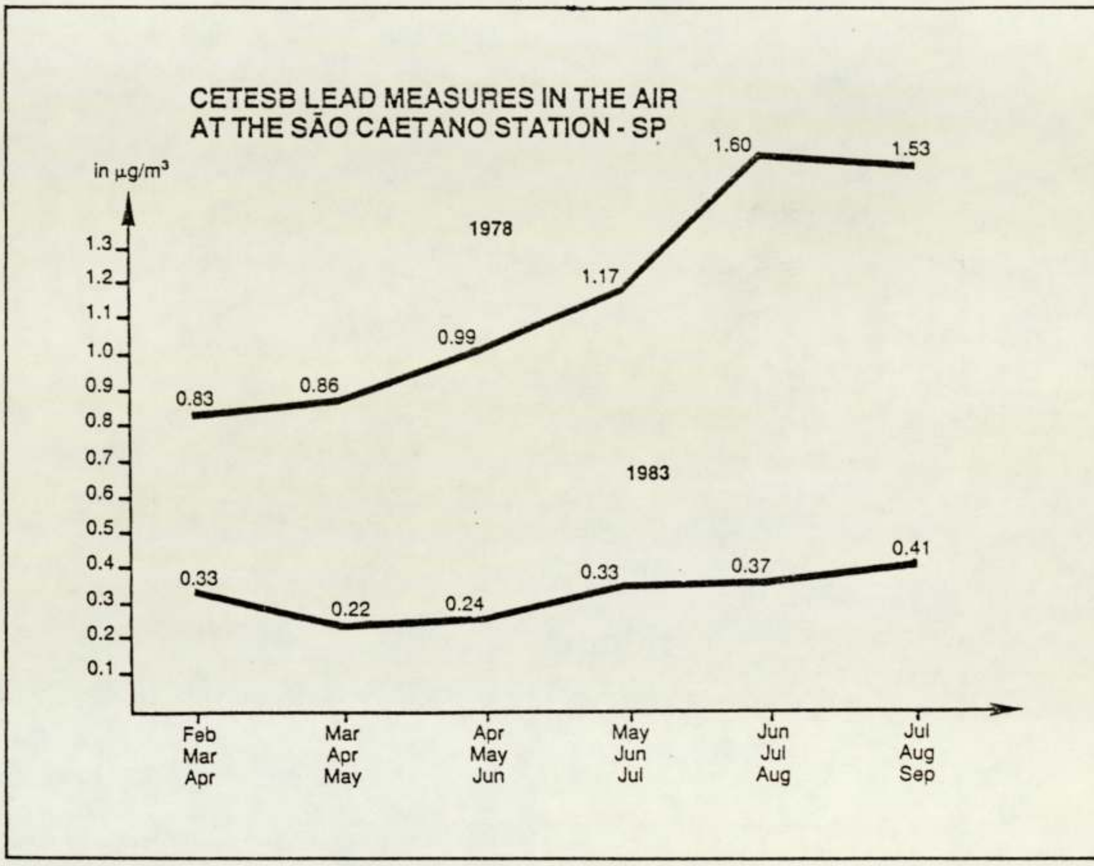
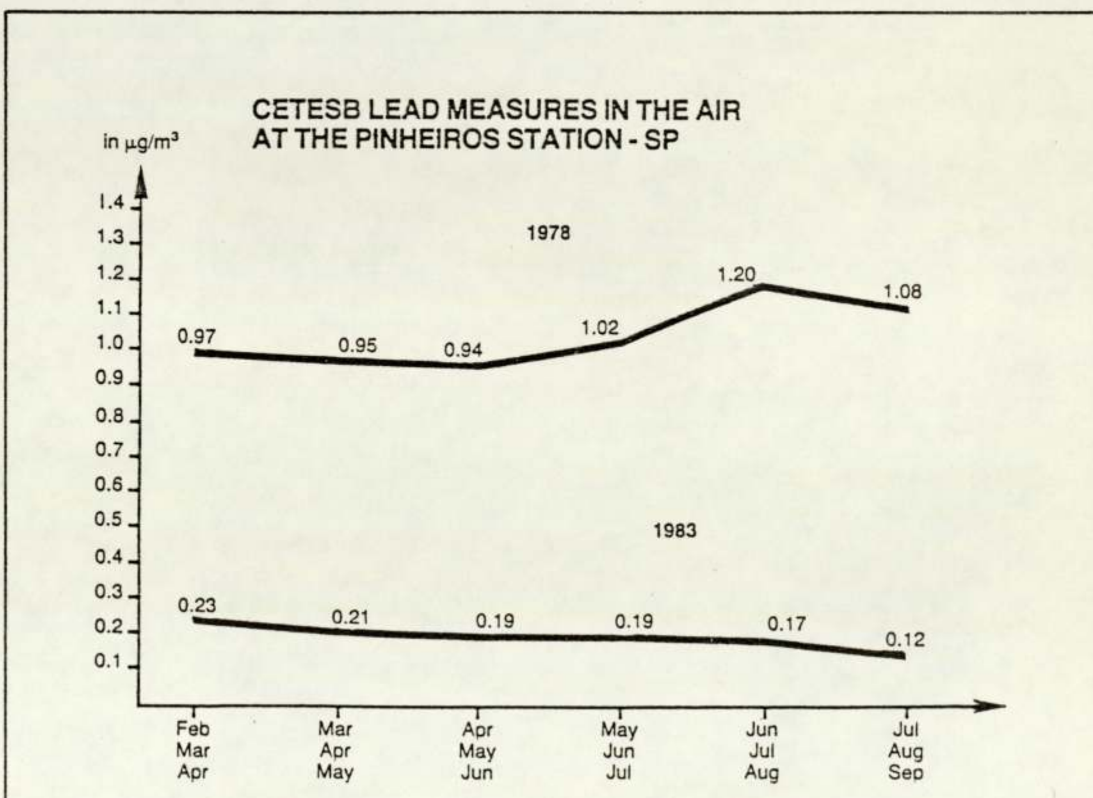

EMISSIONS OF LIGHT VEHICLES (grammes/km) Source: CETESB
Alcohol Vehicles
New Gasoline Vehicles
Gasoline Vehicles pre 1980
grammes/km
55
50
45
40
35
30
25
20
15
10
5
4
3
2
1
0
54
37
18.5
4.7
3.3
0.9
1.2
1.4
1.2
0.05
0.05
0.18
CO
HC
NOx
ALDEHYDES

Figure 8.2





Source: CETESB

strong moral connotation that serves to make the subject somewhat troublesome. To produce fuels instead of food is a matter for serious concern.[40]

What many people do not realize is that the problem is not lack of food, but that is utterly unequally distributed. As Hall puts it, the world produces 10-20% more food than is required to feed its people an adequate diet. The world grain stocks will be around 207m tons in 1984-85. In the EEC, there were 30m tons of grain surpluses in 1984; this year the community will produce, just in the dairy sector, 12m tons more than it can consume. Thus the main problem is not lack of food, but how to distribute equitably the existing ample supplies of food.[41]

In addition to enormous waste, a huge amount of agricultural production goes to animal feed. If, e.g. the world soya bean production was to be diverted from feed to direct human consumption, would provide 5 Kg. per year of high protein food (750 Kcal. energy/day) per person in the world. In the USA, 91% of vegetable protein and 70% of UK primary products of agriculture are fed to animals; and in the world as a whole, 40% of the cereal production and 30% of the total protein production is fed to animals.[42]

As for the global agricultural production potential, a FAO Study argues that the world could produce enough food to feed 33 billion people, seven times the present world population!! Using somewhat less sophisticated farming methods, 15 billion people could be fed. And even if the whole world relied on primitive farming method, the present world population could still be comfortably fed.[43] Even the developing countries could support, with low level of input, one and a half times their projected population (3.6 billion) at the end of the century.[44]

It is a human tragedy that while there is so much food available, so many millions of people die of hunger every year in the world. At the same time, in some of the industrial countries, governments, from both right and left, are calling for population growth as a spur to economic growth.[45] These examples suffice to illustrate the fact that the root problem is not the lack of physical resources (e.g. agricultural land), but basically political factors. One cannot condem the farmer for producing the fuel for his tractor, without questioning the whole system of food production and utilization patterns.

In the particular case of Brazil, the "food vs. fuel" problem has been, in my view, grossly exaggeraged. The roots of the problem were explained in 2.1. No one would deny that there have been problems which are to be found within a wider economic and political context. If one examines table 8.5, agricultural production for domestic consumption has declined considerably. From an index of 100 in 1977 it fell to 84.9 or 87.1 in 1984, depending on the source, despite a population increase of c.15% on the same period. During that period there has been a rapid expansion of export oriented crops, notably sugarcane. The main explanation should be found in the government agricultural policy. If one considers the most important commodity crops only, the rapid increase of sugarcane, bean, and soya bean stand out. Examining the crop planted area, these differences are not so dramatic, in the case of sugarcane. Most of the other crops occupy far more land - e.g. corn 12.5×10^6 ha. and soya bean with 9.4×10^6 ha. Soya bean expansion has been a major cause in displacing many small farmers, particularly in the state of Parana. Soya is highly mechanized, which means few jobs, and exported mostly for animal feed to the West. Sugarcane occupies 3.8×10^6 ha. and that includes sugar and alcohol production. One should recall also the fact that a large percentage of sugar production is destined to the domestic market.

It is important to consider how this expansion took place (in this case, sugarcane). Brazil has, as noted, large expanses of underused land. A good proportion of sugarcane expansion has been in pasture land, albeit not all. With a guaranteed market, sugarcane offered less risk on investment than many traditional crops. A market economy responds to market forces. This is the case with most export crops.

Table 8.5 Domestic Growth Per Capita of Agricultural Production.
(Index 1977= 100)

Year	Domestic	Export	Sugarcane
1984(a)	84.9	113.3	174.8
1984(b)	87.1	114.8	166.5

Production of Main Commodity Crops.(Index 1980=100)

Year(b)	Crop	Index	Ha.(10^6)(c)
1984	Rice	86.0	5.3
1984	Bean	106.3	5.3
1984	Corn	101.6	12.2
1984	Cassava	85.9	2.1(1982)(e)
1984	Cotton	96.6	3.6(1982)(e)
1984	Soyabean	105.9	9.4
1984	Coffee	-	2.2(f)
1977/84	Sugarcane	166.5-174.8	3.8(1984)(f)

Sources:
(a) Homen de Melo F, The Brazilian Energy Policy and the Alcohol Programme,Paper presented at the Conf. on the Brazilian PNA:Issues and Perspectives; University College London, 24 May 1985.
(b) Rodrigues R. Bases para o ProAlimento, STAB 2 (5) May/June 1984, pp.6-7, table 2.
(c) SOPRAL Informativo, November/December 1984, p.31
(e) IBGE 1983.
(f) Ibid.1984. See SOPRAL Informativo 3 (26) December 1984, p. 31.

The main problem, however, is not too much sugarcane, but that it is too concentrated in the region of Rebeirao Preto, SP - incidentally the greatest food production area.[46] This concentration is not due merely to the ProAlcool, but because the region offers the best advantages (e.g. good land, infrastructure, entrepreneurship, skills, etc.), and of course lack of political action. This latter factor, however, is changing due to a new policy of the government of the State of SP to prevent further concentration.[47]

Being the State of SP the greatest producer of sugarcane, the rapid expansion of the ProAlcool caused, and rightly so, much concern. In 1980 the IEA (Institute of Agricultural Economy) carried out a study in which fears were raised that this expansion would displace many traditional crops.[48] This analysis seems to have been based on a number of assumptions which did not materialize. For example they thought that 65% of the planned 10.7×10^9 litres of alcohol for 1985/86 harvest would have come from SP. This would have increased the planted sugarcane area from 1.2×10^6 ha. in 1980, to 2.6×10^6 ha. in 1985. The rapid expansion to non-traditional sugarcane growing states such as MS, GO and MG, brought down the share of SP to 50% in 1984. Even within the state of SP, the expansion of the past few years has taken place in non-traditional areas, like the "Alta Paulista". There are in SP 21.8×10^6 ha. of which only 6.4×10^6 are cultivated.[49]

New alternatives are also being investigated to increase food production in sugarcane growing areas e.g. intercropping. This new policy is called "Projecto Cana e Alimentos" or "ProAlimento", and may become an important instrument to grow traditional crops. In 1983, Rebeirao Preto produced 6×10^4 tons of grains by this system.[50]

In summary, one may conclude that the threat of biofuels to food production has been exaggerated. Unequal distribution, waste and politization of food are greater dangers. Biofuels, if properly managed, could play an important role in forcing the pace of agricultural modernization by providing the high-cost fuels locally, or in reducing foreign exchange burdens. What is needed is the political will to ensure they are used properly.

8.5 Net Employment

Job creation has usually been regarded among the most beneficial contributions of the ProAlcool. I will consider three main aspects: (i) net employment creation; (ii) seasonal character; (iii) investment cost per job.

Estimates on employment vary considerably, as a consequence of regional differences, topography, mechanization levels, labour productivity, salaries, etc. These estimates vary from 0.04 men ha./year of planted sugarcane, to 0.6 men ha./year. Between 80 to 85% of jobs in sugarcane are unskilled. The rest can be regarded as semi-skilled or skilled (e.g. mechanics, tractor operators, administrative). In the industrial phase the proportion of skilled workers raises to 52%.[51] Table 8.6 shows to employment in a 1.2×10^5 litres/day distillery, for both agricultural and industrial phases. It is interesting to note the enormous regional differences. The North-East employs far more people than in the Centre-South, notably in the agricultural sector due to low mechanization levels.

In the next table, 8.7, are shown the direct employment impacts of the PNA, according to the alcohol producer estimates. Pereira, on the other hand, has estimated that the programme created 15939 new jobs in 1980 and 48728 estimated for 1985. But when all year around employment is considered these figures are 164000 and near half a million respectively.[52] The figures released by CENAL for 1984 were 4.25×10^5 direct jobs in the production of 9.3×10^9 litres of alcohol; 0.65×10^5 correspond to the industrial sector and 3.6×10^5 to the agricultural phase.[53] CENAL figures give the overall employment only, but one may suspect they correspond to the equivalent full time jobs (that is, including temporary and permanent jobs). These figures, however, can be misleading because the difficulties of quantifying employment on the basis of a common denominator. Neither do they consider net employment (e.g. jobs replaced by the

Table 8.6 Estimated Employment Associated with a 120m3 litres/day Alcohol Distillery, 1981-1985.

	Centre-South		Northeast	
	1981	1985	1981	1985
Total jobs(men/year)	640	570	2 100	1 750
Agricultural phase	490	420	1 950	1 600
-permanent	245	210	975	800
-temporary	245	210	975	800
Industrial phase	150	150	150	150
-permanent	87	87	87	87
-temporary	63	63	63	63
Persons employed(sometime during the year)	948	843	3 138	2 613
Agricultural phase	735	630	2 925	2 400
-permanent	245	210	975	800
-temporary	490	420	1 950	1 600
Industrial phase	213	213	213	213
-permanent	87	87	87	87
-temporary	126	126	126	126
Index of total employment (men/year per million litres of alcohol)	32	29	105	88
Agricultural phase	25	21	98	80
-permanent	12.5	11	49	40
-temporary	12.5	11	49	40
Industrial phase	7.5	7.5	7.5	7.5
-permanent	4.4	4.4	4.4	4.4
-temporary	3.1	3.1	3.1	3.1

Source:

Coalbra: Alcool e Emprego: O Impacto da Produção de Alcool de Cana-de-açucar e de Madeira na Geracão de Emnpregos. Cadernos Coalbra-3, 1983, p. 74, table I.26.
(Note: It is a summary of the main componets only).

Table 8.7 Number of Direct Jobs Created by the Ethanol Production
(In cummulative figures)

Period	Number of Direct Jobs
1975	28 200
1976	32 900
1977	70 500
1978	117 500
1979	159 800
1980	173 900
1981	197 400
1982	272 600
1983	371 300
1984	423 000

Source:
The Brazilian Ethanol Producers' Special Committee, Ethanol:Brazil Export Potential (undated), p.12, table 8.

Note: The number of inderect jobs created by the ProAlcool, according to this source, is 1.8 million.

expansion of sugarcane).

Coalbra has carried out an important study on the employment impacts of sugarcane and wood alcohol production. According to this study to produce 10.7×10^9 litres of ethanol from sugarcane would generate 5.1×10^5 full time jobs equivalent per year. To produce the same amount from wood would create 4.2×10^5 jobs ($20m^3$ of wood per ha./year). These figures are very significant if one considers that during the 1970s, agricultural employment in Brazil increased by two million only.[54]

The important question is, however, to know how many new jobs are actually created. Coalbra estimates that between 54.7 - 62.5% of the employment generated in the regions of Campinas, R. Preto and Bauru-Meralia in SP, during 1974-1979, were existing jobs. That is, only between 55.3 - 37.5% of these jobs were actually new. Although the proportion of new jobs in Alagoas and Pernambuco was c.68%[55]. This means that sugarcane expansion has served, in the main, to save rather than create jobs - excluding the industrial phase. Indeed, when such expansion has taken place in traditional crops growing areas (e.g. cassava), the employment impact would have been negative, because subsistence crops are more labour intensive. Nonetheless, two points need to be added: (i) a large expansion of sugarcane (particularly in the past few years) has taken place in pasture or underutilized lands; (ii) sugarcane is one of the most labour intensive crops. It employs 21.5 - 22.5 men ha./year as opposed to 2 men ha./year for soya bean.[56]

Another problem associated with sugarcane is the seasonal nature of employment as illustrated on Table 8.8, in the case of SP. This is, however, the nature of agricultural employment in general.

Table 8.8 Seasonal Character of Eemployment for Main Crops in Sao Paulo

Crop	Index of Seasonal Concentration of Employment
Cotton	37 to 44
Orange	7.8
Rice (non-irrigated)	7
Soya bean	3.5 to 12
Beans	3 to 4.5
Corn	1 to 4.5
Sugarcane	2.2
Coffee	2

Source: Borges J.M., Oferta e Custus de Produção de Alcool in Brazil, Proceed III CBE. op. cit. p.1538

As can be observed, only coffee offers more continuous employment than sugarcane according to Borges. An additional advantage of sugarcane is that this employment occurs at different seasons of the year in the different growing areas - from June to November in the Centre-South, and November to April in the North-East. This means that labour force can move from one region to another, although it is undesirable for social reasons.

With regard to investment cost per job, Geller gives a figure of $23-28000 in the Centre-South and between $6-7000 in the North-East (in 1983 dollars). This includes land cost, investment in distillery; farm equipment and parity exchange rate. This compares with an overall investment of $42000 in the industrial sector; ($70000 in intensive activities such as minerals, paper and pulp); and about $20000 in the petrochemical complex at Camacari (BA).[57]

Coalbra gives a figure of $22000 ($30000 for wood ethanol) and disagrees that employment creation is a special advantage of the ProAlcool.[58] But Sabino Ometto quotes a figure of $12-22000. However one should bear in mind that these jobs are created where they are most needed: the rural sector. This would bring additional economic and social benefits, by keeping the population away from overcrowded urban areas.

8.6 Constraints and Criticisms

With all the constraints and difficulties, the ProAlcool represents a new and important approach to energy policy in Brazil, and beyond, because the implications for the development of alternative energy technology. As any pioneer programme, it has had its drawbacks. Firstly, it was launched at a time of high energy vulnerability and with deepening balance of payment problems. Energy policy requires a long span. It is not possible to make policy changes every time there is a fall or raise in the oil prices. Alcohol supply is highly inelastic, because for the time being at least, it cannot be imported. On the other hand, from the planning of a new distillery to full production capacity takes about five years. Unlike oil, weather plays an important role. At the same time alcohol demand is strictly linked to the performance of the automobile industry, which is very much a function of the domestic and the international markets.[59]

The ProAlcool has been termed by some critics as "elitist". This is refuted by Penna, firstly because the enormous subsidies that many other sectors receive from the government, particularly public transport, domestic households (e.g. LPG), partly paid from the sale of gasoline; secondly because the car is used by an increasing proportion of the population as an instrument of work. At the same time the automobile industry is a major source of employment. Nor is the programme inflationary since the price of alcohol is kept below that of gasoline.[60]

Brazil's energy dependence is undergoing dramatic reversal, in which the PNA is playing a significant role. At the same time the programme is contributing in a number of other ways. First by forcing the pace of innovation in both agricultural and industrial sectors related to the ProAlcool. Secondly by creating and saving many jobs, and new skills.

Government intervention in the PNA has been a main criticism. But is it not the case that energy production is an activity in which governments all over the world have become involved, providing taxes and regulating sales and consumption?

Brazil is a country which historically has had difficult conditions for private financing in capital markets, because high inflation rates, government regulations and control of savings accounts. In such a situation, the acquisition of real assets is the prime way to hedge against inflation. Since private savings are lacking to finance investments, federal and state banks have become the prime lending agencies, charging low marginal interest rates. The result is that significant capital gains are realized by borrowing from government at negative real rates of interests. The more one can borrow from government, the greater are the realized capital gains. This applies either if you borrow to build an alcohol distillery or a bakery.[61]

According to Homen de Melo, the PNA went ahead despite being uneconomic, because of a powerful coalition of interests (e.g. the sugarcane lobby, alcohol producers, capital foods sector, the automobile industry in the later years, and the mid/high income families as consumers). He argues that the PNA would have benefited more the middle classes than the poor. He fails to go to the root of the problem: the poor hardly benefit at all from the Brazilian society as a whole. Regardless of the well intentioned and much justified criticism, that some of the most outspoken opponents of the PNA have been making, they have failed to come out with any credible alternative or answer in my view. Take for example the technical alternatives mentioned by Homen de Melo, none of which appeared to be a realistic alternative at that time. A Brazilian Journal referring to one of such critics puts it in a correct perspective:

> "Gurgel critica o ProAlcool, mas não justifica."
> (Gurgel criticizes the ProAlcool, but does not justify it).[62]

The ProAlcool is not, and never has pretended to be the cure to Brazil's problems. Perhaps it created too many expectations, particularly on the socioeconomic front, which did not materialize. But critics who question such a role, should do so within the Brazilian socioeconomic order from which the ProAlcool emanates. It would be politically naive to expect the PNA to act as an important channel to cure Brazil's social problems, particularly when its own survival was at stake for years. With a more secure future, at least in terms of achievements, and with a new Administration more concerned with socioeconomic justice, one would expect that social considerations would play an increasing role in shaping the programme's objectives.

CHAPTER 9

GENERAL CONCLUSIONS

The preceding chapters have illustrated and analyzed the role of the ProAlcool, particularly with reference to technological contribution and developments. It remains to draw together the main findings, assess the thesis's objectives and see what lessons can be learned and what policy recommendations can be made.

At first glance, it seems reasonably clear that four out of the five broad objectives of the P.N.A. have been achieved to different degrees. The social objectives, remain in the main, unfulfilled. One of the most remarkable successes of the ProAlcool has been its role in reducing Brazil's external energy dependency (figures 1.2 and 2.2). Thus President Figuereido's statement on energy independence, is becoming a reality (section 1.6.1). Although such achievement is due to a combination of other factors, no one can deny the key role of renewable energy sources. The P.N.A. is a new and important factor in Brazil's energy policy.

Much of the conventional wisdom on energy needs reconsideration. The dismissal of new alternatives, particularly by conventional energy agencies, is quite often done on questionable grounds. Often renewable sources of energy are condemned for not providing what non-renewable forms of energy could not provide. Such attitude is without logic. Renewables, surely create problems for economic viability - and so many other conventional energy sources - at this moment. But energy policy has to be considered on a long-term basis. Renewable systems that are undertaken at this moment in time would not be coming in full operation until the 1990s. At that time, demand for non-renewable sources is expected to increase.[1]

Alternative energy technologies are also accused of poor reliability and standard of performance, compared with conventional energy. It is often conveniently forgotten, that it is only after decades of experience and improvement, of "trial and "error", that such performance has been achieved. For example, the internal combustion engine has reached its present level of viability only after more than 60 years of experience. It is the story of all technical change and development. An additional factor, seldom considered, is the environmental cost of conventional sources of energy. Renewables, particularly biomass, are infinitely preferable than say, nuclear energy or petroleum.

There is also the function of sustainability of non-renewable supplies, particularly oil. Therefore, the more renewables we use, the longer can be extended the "life span" of non-renewables, in particular oil. An additional factor to consider is "economic" and "energy independence". For many developing countries, renewable energy is the only available option to reduce external dependence. Hence the optimization of these resources is an imperative necessity for many poor countries.

On the social front, renewable energy sources can make much greater contributions. They make much easier decentralization, rural development, environmental preservation and social equality. Much of the development that has taken place in developing countries over the past decades, has been concentrated in a few urban zones in each country. Some of the social consequences of this western-type of development - based on capital intensive energy technology, has been rural decay, large sectors of the urban masses living in shanty towns, and concentration of economic and political power in the hands of a small sector of the population.

Present energy scenarios fail to recognize that energy demand is very much dependent upon the model of development chosen, and that the choice of energy technology is an important determining factor. In that sense, the ProAlcool is a step forward to a less centralized and less capital intensive energy technology model.

9.1 Obstacles to the Energy Transition

The growing energy-intensiveness of industrial production has confronted the oil importing developing countries, with two major problems. First to find the financial resources with which to pay the increasingly costly import fuels bill, which has increased dramatically despite the fall in oil prices since the early 1980s. Second, these countries have already faced the urgent task of restructuring their industries to use other resources of energy in place of oil. The P.N.A. is the best possible example.

The search for new energy sources is not an easy task for most developing countries, given their limited technological experience and lack of financial resources. On the other hand reliance on continued imported energy imposes real limits on the expansion of the national industrial base.[2] Introduction of new energy sources, particularly alcohol fuels, may have to be done more on political than economic grounds, given the current oil situation and the state-of-the art of alcohol technology. But prevailing hydrocarbon fuels pricing policies which promote consumption of diesel and gasoline, and lack of societal consensus, makes the politicians' task a difficult one.

Market penetration barriers are, on the whole, hostile to new energy sources of which alcohol fuels are no exception. Firstly because any society requires time to develop and accummulate experience in the energy facet of its economic and social life. Secondly, the traditional Energy Agencies try to create insurmountable obstacles to new energy sources[3] (section 1.3). Table 9.1 illustrated the main market barriers to ethanol fuels. As can be seen, institutional constraints, together with financial and technological barriers, are the main difficulties. These selected countries are all biomass rich ones and with strong interest on ethanol fuel programmes

There are also other important social obstacles to biomass-related energy, worth recalling. Biomass is a disliked term in developing countries, something they want to get away from. This is because it is seen as the "poor people's fuel",

TABLE 9.1 Market Penetration Barriers to Ethanol Fuels in Selected Developing Countries

	ARGENTINA	BOLIVIA	BRASIL	COSTA RICA	PARAGUAY	REP. DOMINICANA	KENYA	MALAWI	ZIMBABWE	INDONESIA	PHILIPPINES	THAILAND
Institutional Constraints												
national program	-	-	+	-	±	-	-	o	o	±	-	±
Consumer attitude	o	o	±	-	±	o	o	o	o	o	-	o
automaker, motor trade and allied industries	±	o	+	-	+	o	±	o	o	+	o	o
oil marketers/retailers	+	±	±	+	+	o	-	+	+	o	o	o
refineries	±	±	-	+	±	+	±	o	o	o	o	o
ethanol producers	+	o	+	-	+	+	+	+	+	o	+	±
farmers	±	±	+	-	+	±	+	+	o	+	+	±
sci/tech community	±	-	±	-	-	-	±	o	o	±	±	±
Economic/Financial Constraints	±	±	±	-	±	±	-	±	±	-	-	±
Pricing Constraints	+	-	±	±	±	o	±	+	o	-	-	±
Tech. Transfer Constraints	±	-	±	±	-	-	-	±	±	±	±	±

Legend: o unknown; + affirmative; - negative; ± uncertain

Source: Trindade S.C. Implementation Issues of Alcohol Fuels: An International Perspective, Proceed. VI International Symposium of Alcohol Fuels Technology, Ottawa, 21-5 May 1984, p.4.10, table 1.

which carries little or no prestige. Thus any new form of energy seems to imply the use of reasonably advanced technology if it is to have any chance of success with the decision-maker. "Biofuels", e.g. - regarded by many people as the "rich people's fuel", uses modern technology in both the production and utilization phases. Therefore an "energy transition era" is as much a social than as an economic and technical problem.

Every time that such a transition has taken place, there has been significant economic, technological and social changes. For example, the charcoal-based era led to the steam-engine; and the steam-engine era to the internal combusion engine. Each of these phases represented a new economic and social period of history. The internal combustion engine led to the creation of the automobile industry on a global basis, and to the creation of a new industrial complex - i.e. the transport system.

In the case of Brazil, due to its late industrialization, the country entered the transportation era when this new trend was already consolidated. The consequence was that this technology was transferred to Brazil without considering other alternatives to the transportation system. During the previous phase (the steam-based) had a limited impact in Brazil since railway transport was limited to link the export-oriented regions - e.g. the coffee-growing areas of S.P. State.[4]

However in this new transition, at least so far as renewable energy sources is concerned, Brazil is playing a leading role in many ways. This represents a remarkable achievement. The main problem in the present Brazilian situation, is that the shift to the biological-based energy technology is not being matched by social and economic change. It continues to serve the same traditional interests, though it is historically the case with previous energy transition periods, in all countries.

9.2 Challenges for the Late 1980s and 1990s

The past few decades have witnessed enormous scientific and technological advances in a scale never seen before. These advances have been very uneven and have had very different results. The years ahead will bring even more technological changes, particularly in microelectronics and biotechnology. We are, perhaps, leading into a new phase of evolution of intellectual capability. But despite this human advance, many human problems and wants remain unsolved and unfulfilled for the majority of the population.

As a matter of fact many people in the poor world are much worse than a decade ago, because of economic stagnation, financial problems and industrial changes. Thus important policy changes can be expected if present problems are to be solved. For example the performance and growth of world's industry in recent years, suggests a distinct departure from the experience of previous decades. This departure involves very basic changes that go beyond the mere slow-down in world economic activity which occurred in the late 1970s.

Composition of manufacturing activities is rapidly changing, with many of yesterday's major growth industries - e.g. steel, stagnating while new ones are taking hold.[5] Simultaneously new issues involving technology, finance, trade, etc, are emerging. In the technological field, the extensive introduction of electronics and biotechnology, may substantially alter comparative advantage and the international division of labour of industrial products.

At the same time it will be more difficult to keep pace with the general technological developments. The main difficulty for many Third World countries would not be that technology cannot be obtained, but that fewer and fewer national economies will be able to finance technological development, and to create an industrial background capable of adapting new technology. On the other hand, the strained financial situation is bound to produce significant changes in the general economic policy of many countries, which in the 1970s had increasingly concentrated on export orientation.[6]

In the past 40 years, economic and social change in developing countries can be described best as dependent development, this has neither helped to meet the basic needs of the world's poor, nor created independent strength in capital goods sector, engineering, etc. Industrialization was based on increasing import of technology which has led to increasing financial cost and increased technological dependence. There is an enormous imbalance in the global distribution of scientific and technological potential, with over 95% concentrated in the industrial countries. While the South accounts for 9-10% of world industrial output, its share of research expenditure is 3-4%. The industrial countries spend about $150 billion annually (51% on military and space research) on scientific research, of which less than 1% is somehow related to the needs of the South.[7]

To cope with the harsh realities reflected in the unsolved problems and lessons, the South requires bold and radically different strategies if these nations are to harness the potential of S&T.[8]

It is under this background that the ProAlcool should be examined, and why it becomes important, if one considers the programme leading role in the development of biomass-based technology. This technology should become increasingly important in the economic and social development of many developing countries, and one of the best hopes for greater energy and technological independence. It constitutes one of the best testing grounds and guarantees that renewable energy technology would become increasingly part of the economic mainstrain.

9.3 The P.N.A. Contribution

Thus, what has been so far the major contribution of the P.N.A.? Such a contribution must be analyzed according the main issues in question. The Pro-Alcool has had a far-reaching influence beyond Brazil itself. For example, the USA gasohol programme was greatly influenced by Brazilian events. The appearance of ethanol-powered cars in Brazil has accelerated developments elsewhere in the automobile industry. The P.N.A. represents a new element in energy policy, and one of the few successful Brazilian projects.

On ethanol production and utilization, the success of the programme is beyond doubt. This success is still more remarkable if one considers that such an achievement has taken place in the background of Brazil's deepest economic crisis in living memory. In just a few years, thanks to the P.N.A., Brazil created the conditions for large scale production of industrial alcohols on a scale unknown previously in the world.

According to the Director of the World Bank, Isaac Sam, the P.N.A. is one of the most successful programmes financed by the World Bank.[9] On social issues the programme achievements are more questionable (see 9.3.2). I will examine the main contributions of the ProAlcool in more detail.

9.3.1 Technological Contributions

The technological and scientific contribution of the ProAlcool should be considered within a wider national context. Brazil's industrialization process was based on massive import of technology, as seen in section 1.4. This policy has had a negative impact for the autonomous generation of technology in the country. The Brazilian industrialist has been too keen to import technology than to risk his capital on R&D.

The university system has tended to form personnel not as a response to market demand, but more as a desire to reduce cultural differences between Brazil and the industrial countries. The creation of technical capability played a secondary role. Full exercise of scientific activity without cultural colonianism and with freedom of activity and purpose remain a myth in Brazilian universities.[10]

In this unfavourable situation, generation of indigenous technology was difficult, complicated by lack of an overall S&T policy and by short-term economic considerations.[11] Unlike the industrial nations where the private sector is responsible for large part of R&D, in Brazil the state involvement is of vital importance. The private sector spend 2.5 times less on R&D than the state sector and 7.5 times less, in relative terms, than the private sector in the industrial countries.[12]

A further consideration is the role of the MNCs and their influence on the economy. The MNCs dominate the most dynamic sector of the economy,[13] with much of the technology being imported or 'know-how provided' by the mother company.

Moreover, despite these difficulties, in the area of biomass-related technology, the Brazilians appear to be gaining ground in many areas. The Pro-Alcool has created the basis for the generation of indigenous technology on a scale unknown in most other sectors, particularly in alcohol production technology. This seems to stem from a combination of circumstances: (i) government commitment to alcohol production, with few exceptions; (ii) strong response of the private sector; (iii) Brazil historical and accumulated experience; (iv) in the case of end-use (e.g. alcohol fuel engines), strong support of the MNCs of the automobile industry.

Since the creation of the P.N.A., it is possible to distinguish two distinct technological phases. First, during the first few years of the programme the main concern was to maximize ethanol production, using existing production infrastructure. Production methods were traditional, inefficient and a by-product of the sugar industry. From the early 1980s, however, a new attitude began to take shape - the recognition that existing technology was wholly inadequate to the new reality. Efficiency and increase productivity became two major concerns, and new concepts began to emerge - e.g. the concept "sugarcane-alcohol" gave way to a new concept "cane-alcohol" based on autonomous rather than annexed distilleries. Nonetheless, these changes have been very uneven as seen in preceding chapters. The room for technological improvement is still very large indeed. I will analyze in the following pages the specific technological contribution of the ProAlcool.

The P.N.A. is having a significant impact in agricultural production, particularly in the sugarcane growing areas - e.g. through the use of alcohol-fuelled agricultural machinery. Indeed the programme can play an important role in altering the production system in agriculture - e.g. from a chemical and mechanical oriented to a biologically-based agriculture. This could be done through new biotechnological techniques - e.g. cell/tissue culture and use of stillage as a fertilizer, the use of biofuels etc. This change, however, does not necessarily imply a radical agricultural reorganization, as illustrated by the ProAlcool so far. In Brazil the centralization model of the agro industrial production prevailing in the country has not been affected nor questioned.[14]

Sugarcane is the key factor to the success of the ProAlcool, and remains the only realistic alternative, at least in the short term, for large scale alcohol production in Brazil. Hence Brazilian know-how in this area is confined to sugarcane only. Brazilian experience with other raw materials, e.g. cassava, is very limited. A major difficulty is the high cost of feedstock production (sugarcane) where productivity is still very low, even by international standards.

As for the alcohol production technology, it is a mixture of old and new, in both attitudes and technology. Significant advances have been made in many areas, albeit very unevently. One should bear in mind the lack of worldwide industrial experience in applying contemporary technolgical advances on large-scale production of ethanol by fermentation. This has had a negative impact, in the short-term in the introduction of new processes. A further constraint within Brazil, might have been the dominance of the market of one or two suppliers of alcohol production technology (section 4.2).

This technology has been based, in the main, on simple mechanical principles. This, together with a lack of a R&D programme for the industry as a whole, has led to a weak scientific base. Brazil does not have a technological leadership in alcohol production technology, in the strict sense of the word, since many firms are using foreign know-how for their most sophisticated processes. Looking back to Penna's statements, these appear to be partially true only, for two main reasons: (i) this technological dominance is confined to one single feedstock - sugarcane; (ii) whilst it is true that Brazil has an undisputed position on large-scale alcohol production, the same statement cannot apply to all levels of relevant technology, which remain in many cases, of low efficiency and with many improvements still required.

This is particularly the case with process technology where Brazilian firms are rather weak. Take fermentation technology, Brazil has not developed any process of its own (section 5.4). It consists of foreign technology adapted to the Brazilian conditions. The country depends heavily on foreign know-how on advanced fermentor design, etc. Another area which has remained largely unchanged is distillation technology (section 5.5), which remains too energy intensive and with little Brazilian know-how. Again, many Brazilian firms are turning to foreign know-how to improve their processes.

To this extent one can say that the ProAlcool success, in terms of alcohol production and use, does not match with its technological achievements. But it would be wrong to underestimate the P.N.A. technological contribution, as highlighted in this thesis. However the contribution of the ProAlcool in other areas e.g. cassava technology (section 5.7), cellulosic technology (section 5.8), has been less than one might have expected. In the case of stillage technology (section 5.6) the ProAlcool has generated a great interest and has estimulated new uses. But this problem has been largely the consequence of the P.N.A..

The alcohol-powered car, is of course, the success story of the programme. In just a few years the Brazilians have been able to transfer decades of experience with the gasoline engine into the alcohol engine. Despite the fact that this has consisted of minor innovations in most cases (section 6.4, table 6.3), no one can deny that it is a great achievement to have 95% of all passenger cars running on alcohol, in just a few years. Such achievement is still more impressive if one considers the shift toward heavy-vehicles. There are important alternatives under consideration to tackle the diesel problem (sections 6.5.2 and 6.5.3). The possible outcome of this research is of the greatest interest to many countries.

Yet this is an area where Brazilian contribution is not so clear. This is because the automobile industry is controlled by the MNCs, who were mainly responsible for much of the alcohol engine adaptations. Indeed without their expertise and support (once the idea of the alcohol car was accepted), it is doubtful that the alcohol car would have become a reality in such a short period, despite Brazil's historical experience with alcohol fuels (table 6.1).

One may, arguably, say that the chief Brazilian contribution has been political commitment to alcohol fuels, and technical support - e.g. through the creation of the CAT, to maintain standards. It is possible that the greatest Brazilian technical contribution has still to come - e.g. the development of an engine capable of using more fully the thermal properties of ethanol, now under development in the C.T.A.. Nonetheless, on the whole, we must not undervalue the importance of the Brazilian authorities willingness to use alcohol fuels in large scale and the significance of the ProAlcool as a testing ground.

With regard to the alcohol chemistry industry, the creation of the ProAlcool represented new challenges and opportunities. The industry has matured considerably, despite stiff competition from the petrochemical sector. The shift from petroleum-based processes to biological-based ones, presents additional difficulties because the existing structure allows a barrel of oil to be converted to products in a highly integrated system.

But as illustrated in section 7.3 and table 7.2, the expansion of the alcohol chemistry industry has been remarkable, though much less than originally planned. Most technical processes are of foreign origin. However the creation of the ProAlcool has estimulated R&D in new and improved alcohol chemistry processes (table 7.5), many of which could be improved in the short-term (table 7.4). Therefore this industry does appear to have the technical and industrial capability to become a large supplier of alcohol chemical products and of a sophisticated alcohol chemistry technology, as stated by Paulo Cunha. A clouding factor is political uncertainty (table 7.6) and market difficulties.

An alternative would be to expand the present sucrochemistry sector (section 7.6, table 7.8) which will not be in direct competition with petrochemical processes. For this, however, Brazilian firms lack presently the technical know-how.

9.3.2 Social Contributions

The social contribution of the ProAlcool is full of contradictory arguments. One reason being that, despite the proclaimed objectives of the programme, the military regime was mainly concerned with economic not social development. To be more precise, alleviation of poverty never has been a top priority in Brazil for the past 50 years. It is only now that the present government has said that social issues will be given top priority.[15] If it is fulfilled, then one can reasonably expect that social problems will play an increasing role in the P.N.A.'s objectives too.

The truth of the matter is that it was unrealistic to believe that the ProAlcool would be the panacea to cure Brazil's social ills. To say that the programme benefited more the rich classes than the poor ones, is to ignore Brazilian reality. The ProAlcool was superimposed on the existing economic structure. The subsequent changes, particularly in the agricultural sector, responded not to the needs of the rural economy, but to the rationale of the capital.[16] Some critics have questioned the social achievements of the P.N.A. but without questioning the whole economic and social system.

It is difficult to judge the ProAlcool for these reasons and because of the many shadow benefits (e.g. greater energy independence, political considerations etc.). There is also a further factor, seldom considered, which concerns the role of the ProAlcool as a major testing ground for renewable energy sources. These are long-term benefits, far beyond Brazil interests, and for which may be worth paying a certain price now.

In considering the costs of producing alcohol, all items must be accounted for - i.e. subsidies to the oil industry such as oil exploration,[17]; transport subsidies, particularly diesel oil and LPG; real cost of oil imports which Brazil has to buy with borrowed money; interest rates, subsidies to other energy industries such as nuclear and hydroelectricity, etc.). When all these factors (or a few of them) have been taken into account, the cost of alcohol fuels and petroleum does not compare unfavourably (see section 8.2.1). This excludes other quantifiable/ unquantifiable social benefits.

Take, for example, the environmental implications for which the P.N.A. has received severe criticism. No one can deny that the programme has increased the volume of stillage dramatically. It is heavily polluted, but so is the oil-based industry - i.e. refineries, petrochemicals etc. Still worse, being Brazil a country where environmental quality plays a secondary role, pollution control never has been a main preoccupation of the politicians. So everyone pollutes, and very few clean up. Thus, the ProAlcool also should be judged within this context. But the use of alcohol fuels brought important positive impacts too, e.g. lower emission levels caused by the alcohol-fuelled cars (see figs 8.1 and 8.2) and due to lower demand for gasoline. These facts are rarely mentioned by the P.N.A. opponents.

Food versus fuel has been another major criticism. This tends to overlook a number of important issues. First, agriculture has been historically the source of many non-food products.[18] Second, this argument ignores the real world food situation of waste, surpluses and unequal distribution of food (section 8.4). Third, it does not give full credit to the need to produce high cost energy locally. The basic problem is not lack of food, but the political will to ensure that there is equitable distribution.

In the specific case of Brazil, two main aspects have been grossly ignored in my view, (i) government agricultural policy (section 2.1, table 8.5). (ii) that sugarcane expansion has taken place mostly in pasture land. Sugarcane overconcentration has been confined to specific areas - i.e. Ribeirao Preto, S.P., which also happens to be Brazil's greatest food production region.

Finally, let us consider the social benefits of job creation. This should be regarded as positive for three main reasons: (i) the P.N.A. has created many new jobs in the industrial sector (plus many more indirect ones); (ii) in the agricultural sector many jobs have been saved and many more have also been created (see table 8.7); employment in the sugar and alcohol sector represents nearly 4% of the entire Brazilian agricultural force; (iii) investment cost per job is among the lowest in any industrial sector. This is particularly important in a country like Brazil.

9.4 Summary and Policy Recommendations

With all the deficiencies and pitfalls, the P.N.A. can be regarded, on the whole, a particularly successful one. It is a pioneer programme which is so much based on "trial" and "error". The ProAlcool has achieved to a great extent most of the broad objectives stated above. This is particularly the case in terms of increased alcohol production capacity and end-use. The greater energy independence achieved in the past few years, is of great significance if it is considered in terms of gasoline replacement. One should also bear in mind that the ProAlcool was launched at a time of extreme energy vulnerability and of deep economic and financial crisis in the subsequent years.

In addition, alternative energy sources have many barriers to overcome.

Even within Brazil the ProAlcool had to face stiff opposition from traditional Energy Agencies - e.g. the MME. There are also many social obstacles to take into account. In spite of all difficulties, the ProAlcool is an important energy instrument within the overall energy policy in Brazil.

The programme can be regarded as an important tool for creating the basis for a bioenergy-based technology. In the agricultural sector it could also be considered as an influencing factor for shifting the chemical and mechanical-based agricultural to a more biologically-based one - e.g. through 'biofuels'. The importance of the P.N.A. should be seen from a much wider perspective of a Third World context, and within a new trend towards a new energy transition era. It should be analyzed within a long-term perspective which can serve as an important instrument for further development of new forms of renewable energy. The importance of biomass-related energy technology, consists in the fact that for many developing countries such technology constitutes one of the few alternatives to achieve greater economic and technological independence. To this end it may be worth paying a certain economic price in the shorter term.

Unlike the previous energy transitions, the creation of the ProAlcool is allowing Brazil to play a leading role in the new transition phase. The country has made already significant contributions in this sense - e.g. the political decision to use alcohol fuels on a large scale is by "itself" a significant step forward - although not as much as one would like. The country possesses many of the necessary conditions to develop renewable energy technology - e.g. natural conditions, human resources, etc.

No-one can expect that the ProAlcool would solve Brazil's energy problems, but it widens its policy options. The extent of such a role, is basically a political problem. Hence the energy policy objectives of the new administration is all important, though few changes are expected.[19]

Past failures and current unsolved worldwide problems, will demand important political economic and financial changes. A rethinking of new development strategies. How renewable can be fitted in, remains unanswered, but a greater role can reasonably be expected, because the need to re-orientate economic development towards the use of more indigeneous resources - e.g. the expansion of domestic rather than export markets.

The ProAlcool has allowed Brazil to make specific technological advances in many areas of production and utilization of industrial alcohols by fermentation, despite all the difficulties inherent of a Third World country with high technological dependence. A lesson to be learned of a bioenergy programme as large as the ProAlcool, in that to succeed it needs: (i) political commitment; (ii) strong industrial base; (iii) capability to provide large technical assistance at local levels; (iv) availability of capital; (v) historical experience. Social issues never have been a top political priority in Brazil for the past decades, let alone the ProAlcool. The programme was implemented on top of existing economic structure, without considering any change to accommodate the social problem. Nonetheless one should not underestimate the social benefits derived from the ProAlcool - e.g. greater energy independency, employment etc.

It is not easy or right for an outsider, to sit and judge the ProAlcool, considering the complexities and difficulties of the Brazilian situation. The energy sector is full of cloudy uncertainties, requiring very long-term policy objectives. With regard to possible alcohol demand, this is very much a function of world events in general, of wider national considerations and of the automobile industry in particular. This in turn depends on economic as well as technological factors. Most of these events are beyond the control of the Brazilian energy planners. Having recognised these difficulties, my experience and knowledge of the ProAlcool has allowed me to identify some bottlenecks and policy gaps which deserve further attention.

- Lack of a coordinated R&D strategy. There is a need for an overall policy so as to make better use of scarce resources.
- It appears that the main basis for Brazilian advantage on industrial alcohol technology (by fermentation), is not based on technological leadership, but on (i) accummulated experience; (ii) the production of ethanol on a large

scale; (iii) natural advantages, and early involvement which has given Brazilian firms a headstart advantage.

Such situation is not matched by the same level of technological developments. If the country is to maintain its leading role and to establish this industry on a long-term basis, to take advantage of emerging opportunities in the world markets, then one sees the need for greater R&D priorities. It is also necessary if Brazilian firms want to avoid technological overdependence on foreign know-how, on most sophisticated processes.

- Brazilians must be aware of the new challenges emerging from the sizeable efforts made, and of the results already obtained, by the industrial countries - notably Japan, in alcohol technology. This is likely to erode many of Brazil's present advantages. One cannot see any policy strategy to face this greater competition problem.
- Science and Technology should be playing an increasing role in the future development of the programme, if the ProAlcool is to have a long-term economic future. To this end S&T systems must be capable to respond efficiently and rapidly to the new challenges. Therefore one sees that the S&T system needs to be functionally restructured.
- During the next few years, priority should be given too, to the modernization of old distilleries to improve their poor performance.

If one considers world realities, renewable energy technology would become ultimately, highly sophisticated particularly in the case of biofuels and chemical feedstocks if it is to become a viable economic alternative.

- By-product utilization, particularly sugarcane bagasse and stillage, require greater priority. Research on sugarcane bagasse could produce very important changes in the economics of ethanol production. A new concept "cane-alcohol-bagasse" needs to be formulated. To this end, a further recommendation would be to have clear technical specifications.
- It is of extreme importance that there is some kind of policy to support technology exports - e.g. an "export-support finance strategy", which could

allow to put together technical and finance packages. The availability of long-term cheap credit is as important as the technology itself.

- There is also the need of some kind of policy orientation with regard to ethanol versus technology export priorities.
- With all the difficulties that it implies, a long-term policy objective needs to be established to allow for better planning.
- The alcohol-purchasing policy needs further consideration so as to penalize the less efficient alcohol producers. This could consist in paying some kind of subsidy per each litre of alcohol produced.
- At the moment research is spread out in far too many different areas. A more realistic policy would be to concentrate resources in more selective areas - e.g. sugarcane or cassava, where Brazilian firms could be able to make commercially useful technical advances. This is even more important if one considers Brazilian limited resources, particularly on S+T as seen in section 1.5.

If resources are allocated accordingly and policy commitment is maintained, one can see Brazil on a firm path toward greater energy and technological independence. As the Secretary of State for Mines and Energy stated above,

> "the country who has both energy and technological autonomy, will be able to dictate its own development paths" (..).

Of which the ProAlcool would have been playing a pioneering role, despite the fact that in its original conceptions it did not represent a radical new energy policy. The programme is sufficiently important to warrant serious considerations to economic development policy in LDCs. The P.N.A. first represented as pragmatic approach by a powerful nationalistic "technocratic elite" concerned mainly with rapid economic growth and modernization, and perhaps influenced by new economic development strategies being formulated in the 1970s - eg the N.I.E.O.

The ProAlcool can serve, however, as one important instrument for rethinking a new economic development strategy which will make greatest use of bioenergy resources, away from the high energy technology, that will benefit the majority of the population. This gained importance of the programme stems from past economic development policy failures, unsolved problems and mounting financial, economic and social difficulties which demand bold new development strategies.

If one compares, e.g. the P.N.A. with the Itaipu hydroelectricity dam, a number of important factors emerge which deserve attention. The total investment cost of the Itaipu project is put about $18 billion, producing electricity for industrial and urban consumption. It has flooded hundred of thousand of agricultural land - the reservoir at its masimum level occupies 1460 Km^2. Once the construction phase was terminated, employment is minimum. Investment in the P.N.A. is estimated between $4.5 - 5.7 billion ($6.9 - 8.3 billion if land cost is included), but according to CENAL the programme has saved Brazil $7.3 billion directly on foreign exchange costs (p 244), excluding many other social benefits. The Itaipu project has aggravated Brazil's foreign debt. On the other hand the proposed investment in the energy sector until 1993 (p 40) is $115.5 billion - 91.1% on petroleum and electricity, i.e. $104.5 billion, and just $8.5 billion on alcohol from sugarcane plus energy forests.

Moreover, if once considers the impact of the ProAlcool it seems clear that bioenergy has far greater socioeconomic and technological impact. It requires less capital investment in in absolute and relative terms; uses technology more suitable for local conditions; has created and maintained far more employment particularly in the rural sector, etc - The ProAlcool is, or can be, an important instrument for decentralizing energy installations as - e.g. the alcohol distillers are spread over many places. Very significant is also the fact that bioenergy sources can now provide man with his modern energy needs. This is particularly important for rural development.

INTRDUCTION NOTES AND REFERENCES.

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3 See e.g. Anon. Energy for Rural Development, Renewable Resources and Alternative Technologies for Developing Countries. Report of an Ad Hoc Panel of the Advisory Committee on Technology Innovation. Board on Science & Technology for International Development, Commission on International Relations.National Academy of Sciences,Washington D.C.1981

4 Deudney D, Flavin C. Renewable Energy:The Power to Choose, Norton Worldwatch Books, 1983. See also SunWorld 8 (2) 1984, pp. 34 ff.

5 Biomass energy is a general term that refers to the energy that can be derived from plant and animal materials, through a variety of conversion and end-use processes.See Hall D O, Barnard G W, Moss P A. Biomass for Energy in the Developing Countries, Pergamon Press 1982, p. 1.

6 Ramsey W. Biomass in the developing countries. Energy Policy 13 (4) August 1985, pp.326-329. According to this source the potential annual energy sources from existing forest and waste biomass in developing countries (Latin America, Africa and Asia) is between 1300 to 5600 m.t.p.e.

7 Deudney D. Florin C. *op. cit.*

8 By Industrial alcohols I mean the production of alcohol (by fermentation) in large scale, for modern industrial uses such as fuels and chemical feedstocks.

CHAPTER 1 NOTES AND REFERENCES

1 Bautista Vidal J W, Ex-Secretary of State for STI/MIC from 1974-1978. He formed the first leading team of geologists who discovered oil in Bahia. He was also involved in extensive geological surveys to study Brazil's potential oil reserves. His conclusions are that Brazil's reserves are small compared with potential demand. Personal Communication, 18 May 1983.

2 Another successful military project is the Armament Industry. This industry ranked sixth largest in the world with a turnover of $4-5 billion and a workforce of over 100000. The latest success of this industry has been the contract to supply the RAF with the trainer-aircraft Tucano manufactured by Embraer. The deal worth £125m was won in fierce competition. See The Financial Times 22 March 1985, p 10.

For a more detailed study of the Armament Industry in Brazil see Dagnino R P, Industria de Armamentos: O Estado e a Tecnologia, Revista Brasileira de Tecnologia (R.B.T.) 14 (3) May/June 1983 pp.5-17.

3 See e.g. Brazil State and Struggle, Latin America Bureau, London 1982.

4 See Furtado C. No to Recession and Unemployment. The Third World Foundation for Social and Economic Studies, London, 1984.

5 The tern "Sobornistas" gained its name from a short period of French influence with the Escola Superior de Gerra (Higher School of War). See Brazil: State and the Struggle op.cit.

pp.39-40

6 The Theory of Dependency or "Dependencia" is not well known in the English Speaking World. The "Dependencia" is very much a product of a particular place and historical period of Latin America (LA). The Dependency Theory has dominated the social sciences work in LA. It includes a variety of intellectual traditions. "Dependency" is defined as "a peripheral insertion in the world system through which former colonies and other underdeveloped countries are exploited economically, and their backwardness is maintained over time". See Oteiza E, and Sercovitch F., Collective Self-Reliance:Selected Issues, Intern. Social Sciences Journal 28 (4) 1976, pp.664-71. The literature on the Dependency Theory is very extensive, particulary in Spanish. Recent works in English include: The Dependency Theory:A Critical Reassesment (Editor D.Seers), Frances Pinter, London, 1983. See particulary Palma G. Dependency and Development:A Critical Overview, pp.20-78.

7 The NIEO was set up in the VI UN Special Section of the General Assembly on May 1974 and broadly developed in the Lima in March 1975. See e.g. Feijka Z. Implementing the NIEO: Attempts at Regulating the Structure of World Industry, in Seers op. cit. pp. 150-159.

8 Technology Dependence(TD) mean:dependence upon a foreign service to attain necessary information to manufacture a commodity; TD is essentially a phenomenon of information transfer from one country to another. (b) a nation is technologically dependent if it does not possess the

essential instruments and human skills to be aware of the technological developments. See Doc. IDRC-T918e; Science & Technology for Development, A Review of School of Thought on S&T; Development and Technological Change, Module 1,p. 22. Internt. Develop. Research Centre, Ottawa, Canada.

9 TSR involves the creation and establishment of capabilities for management of scientific and technological knowledge, more than actual knowledge to produce Technology in its hardware (..) or the capability of a country to break even, the so-called "balance of technological diffusion" or the ability of a country to export as much technology as it imports.

See Kim J. Technological Diffusion. A Response to the Question Regarding TD-SR. (STPI Project) in Views on T.D.-S.R. Ed. by O. Cardettini, Doc. IDRC-MR21 October 1980, pp.40, ff. Intert. Dev. Research Centre, Ottawa, Canada.

10 Quoted in Auto-Suficiencia Energética, Ministry of Mines and Energy (MME) July 1984, p. 1.

11 Penna C. O Presente e o Futuro de ProAlcool, CENAL, November 1983.

12 Quoted in the O Estado de São Paulo, 22 May 1984.

13 Quoted in Folha de São Paulo, 2 July 1983.

14 Quoted in Auo-Suficiencia Energética, op.cit. p.1

15 Green K, Morphet C., Research and Technology as Economic Activities, Butterworths, London, 1977, pp.2, 15.

16 Collingridge D. The Social Control of Technology, The Open University Press, 1984.

17 See e.g. Meadows D H. et al. The Limits to Growth, Pan Books Ltd., London, 1972.

18 See e.g. Is Bioenergy Stalled?, Science 227 (4690) 1 March 1985, p. 1018.

19 Elkington J, Sun Traps, Penguin Books, 1984, p. 350

20 Lovins A.B., Soft Energy Paths, Penguin Books, 1977. Briefly the "Soft Technologies options" main characteristics are: i) they are renewable energy; ii) they are diverse, so national energy supply is an aggregate of many individually modest contribution; they are flexible and relatively low technology; iv) they are matched in scale and geographic distribution to the end use needs; v) they are matched in "energy quality" to end use needs. See. pp. 38-39.

21 Many of these concepts have been developed in the North without considering the real interest of those people who it suppose to serve. Hence many of these technologies have failed. See e.g. Appropriate Technology Reader-Theory and Practice in Appropriate Technology. IT Publication, by Charnock A., New Scientist 106 (1455) 9 March 1985, pp.10-11.

22 Dobrska Z. The Problem of Technological Choice, in Seers D. op. cit. pp. 169-180.

23 Ibid . p. 173

24 For example, according to some critics, one of the reasons why the government refused to finance and support the small distilleries was for fear of losing control on production.

25 The Brazilian Nuclear Industry is a point in mind. The Brazilian Nuclear Programme is called "the Nuclear Extravagance". The

programme was set up without much consultation, was partly a response to Argentina's Nuclear Programme, but also for political and technological prestige.
See Pereira , New Scientist, 102 (1410) 17 May 1984,pp.31-33

26 Hall D O. Regional Development Assisted Through Local Renewable Energy Resources, in "Natural Resources and Develop ment in Arid Regions" Eds. E. Campos-Lopez and R J Anderson, Westview Press, Boulder, Col.1983, pp. 165-81

27 Hall D O., Biomass for Fuel and Food-A Parallel Necessity, Paper Presenetd at the World Resources Inst. Symp. Biomass Energy Systems; Building Blocks for Sustainable Agriculture, Virginia, USA, January, 1985, p. 2

28 Ibid .

29 Hall D O, Coombs J, Biomass Production in Agroforestry for Fuels and Food, In Plant Research and Agroforestry, Ed. P A. Huxley, International Council Research Agroforestry, Nairobi, 1983, pp. 137-157.

30 Hall D O. et. al. Biomass for Energy in the Developing Countries; op. cit. p. 27

31 Kemp T. Industrialization in The Non-Western World, Longman, London 1983, pp.130 ff.

32 Hewlett S A. The Cruel Dilemas of Development: Twentieth Century Brazil, Basic Books Inc. Publishers, New York, 1980, pp. 142, 146, 36.

33 Kemp op. cit. pp. 139 ff.

34 Brazil: State and Struggle, op. cit. p. 31.

35 Kemp op. cit. pp. 146-147.

36 Young J M. Brazil: Emerging World Power, Robert Preager Pub. Co., Inc., 1982, p. 48.

37 Ibid pp. 55 ff.

38 See Motoyama S. Política Científica: O Reflexò de uma Dependencia Cultural, R B T 12 (3) July/September 1982, pp. 50-54.

39 See Doc. Política Científica e Tecnológica, SEPLAN/CNPq, Brasilia, 1981. and SNDCT- Ibid. 1982.

40 See Doc. IIIPBDC-Plano Básico de Desenvolvimento Científico e Tecnológico, CNPq. Brasilia, September 1980.

41 Schartzman S. Struggling to be Born: The Scientific Community in Brazil, Minerva, Winter, (4) 1978, pp. 575-578.See also Nature 314 (6011) April 1985, 491.

42 See R B T 15 (3) May/June 1984, pp.58-59.; Casiolato J E , A Responsabilidade de Aplicação dos Investimentos de Ciência e Tecnologia no Brasil, R B T 13 (3) June/July 1982, pp. 43-48

43 For example Law No. 3470 of 28 November 1958, Article 74, limits the maximum amount that a firm (domestic or foreign) can make with regard to the utilization of royalties, trade marks, patents, scientific and technical assistance, to 5% of the firm total sales. See Filho E. Legislação: Fator de Dependencia ou Autonomia? R B T 12 (1) Jan/February 1981, pp.51-53.

44 Particulary hit were biomass-related projects.According to Bautista Vidal most of the 1000 strong research team with the STI/MIC had working from 1974-1978, were made redundant. This team was regarded at that time among the best in the world.

See O Vazio da Tecnologia, R B T 14 (1) Jan/February 1983, pp.58-63. Personal Communication May 1983.

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46 Guedes Pereira M. P&D e Mercado: O Papel do Governo na Intermediação, R B T 13 (3) June/July 1982, pp. 62-68.

47 Despite the growing interest in ST in tha past decade, SEPLAN, on which the CNPq. depended for finance, showed little regard for science. See. e.g. Folha de Sao Paulo, 12 August 1984, p.2 The wind of change commenced with Tancredo Neves whom before he died (see 8.1) created the Ministry of Science & Technology, Headed by Renato Archer.See R B T 16 (2) March/April 1985, pp. 65-68. The scientific community has welcome the move. See Joyce C. Research recovers from the dark age, New Scientist 107 (1465) 18 July 1985, pp. 36-38.

48 See Doc. Programa Nacional de Biotecnologia, Subprograma Engenharia Genetica, SEPLAN/CNPq. Brasilia, 1982.

49 Rosillo-Calle F. Rothman H.The Brazilian National Biotechnology Programme, Bio/Technology, 1(5) May 1984,pp.421-431.

50 See Sub-Programa de Biotecnologia, CNPq. 1984 (Preliminary version).

51 Silva Maria J, As Biotecnologias Aplicadas na Agricultura no Brasil, in Biotecnologia e Agricultura, Ed. A L Ozorio Almeida, Vozes, 1984, pp. 87-100,(p. 89, table 1).
According to the CNPq. the investment in biotechnology in Brazil from 1980-1982 was c. $97.8 m. This figure seems to be too high, even if it includes much of research in the PNA.

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53 Rosillo-Calle , Rothman op. cit., CNPq.(1984) op. cit.

54 Goldenberg J et. al. The Production of Ethyl Alcohol in Brazil, Ciencia e Cultura, 36 (4) April 1984, pp. 550-63.

55 A good example is the Nuclear Programme.

56 Interview given by President Geisel to O Globo, RJ, 7 October 1984, p. 40. See also note 1.

57 MME Auto-Suficiencia Energética op. cit.

58 Ibid

59 Celestino Rodrigues E. Soluções Energeticas, Editoras Unidas, SP, 1983, pp. 65 ff.

60 Koehler C. et.al O Excedente de Energia Elétrica Causado pela Crise e o Estímulo Tarifario da Eletronia, in Energia e Crisis, ed. Pinguelli Rosa L, Vozes, RJ, 1984, pp--. 63-84.

61 MME Auto-Suficiencia Energética, op.cit. p. 23.

62 Idid. p. 46.

CHAPTER 2 NOTES AND REFERENCES

1 By agricultural modernization I mean the change from traditional production methods to modern ones in which modern inputs (e.g. machinery) are used. This also involves intensive utilization of lands, previously cultivated in an extensive nature.

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3 Dall'Acqua F M. Alimentos: Uma década de Crise, R B T 16 (1) January/February 1985, pp. 5-9

4 Assouline G. Marginalização alimentar: O preço da opção agro-industrial, R B T 16 (1) January/February 1985, pp. 11-17

5 Sercovich F C. The Political Economy of Biomass in Brazil. The Case of Ethanol, in The Biotechnological Challenge (A.Jamieson et al.Eds) Cambridge University Press (Forthcoming)

6 It would be wrong to think that the "rural credit" was the only subsidy being paid by the government. Many other economic activities were also subsidized. Total subsidies given by the State, which represented 3% of the GDP in 1973, reached 6% of the GDP in 1980. Se Dall'Acqua op. cit.

7 Figuereido U. O Trabalhador rural e a modernização da agricultura, R B T 15 (4) July/August 1984, pp.12-18. See also

Sheki S. Mecanização agrícola: homen e terra sob impacto, R B T 15 (2) March/April 1984, pp. 5-11.

8 It was not the rural worker who was affected only by the modernization process. Many small farmers were equally affected, particulary in the State of Paraná.These small farmers were forced to abandond their plots of land to give way to the modern plantation (e.g. soya beans) because they could not compete with modern production methods. See e.g.Organização Fundiaria e Desenvolvimento- Uma Contribução ao Debate, Cámara de Estudos e Debates Económicos, Cámara de Estudos de Debates Económicos e Sociais (CEDES) Rio de Janeiro, 1981.

9 Da Silva G. Interview with ZH Journal, Porto Alegre, RS. 23 September 1984, pp.10-11.

10 Land reform (e.g.the distribution of land to landless peasants or the breaking up of large landholdings) is a very sensitive political issue. Every attempt to introduce land reform legislation in Brazil has fiercely been resisted by the traditional landed class, who also happen to be, in the main, the political bosses, particulary in the Northeast. The Sarney's Administration is planning a significant land reform to provide land for 11 million landless peasants. This attempt has already very powerful opponents. It has been termed " a ilha da fantasia"(The fantasy Island).For more details see

O Estado de São Paulo 23 May 1985, p. 3

Ibid 30 May 1985, p. 3

Idid 1 June 1985, p. 3

O Globo 28 May 1985, pp. 1, 6.

O Journal do Brasil 28 May 1985, pp. 1, 5.

Veja (837) 29 May 1985, pp. 114-117

The Sunday Times 2 June 1985, p. 22.

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14 CEPAL.Caña de azúcar,producción de alcohol y los intereses de las Multinacionales en Brasil, CEPAL 1981, pp.21 ff.

15 Barzelay M. The Political Economy of Alcohol Energy in Brazil, Institute of Energy Studies, Stanford University, Cal., Report S-3 December 1980, p. 59.

16 Bautista Vidal J W. Personal Communication 5 May 1983

17 For a full account of the decision-making process of the PNA, see Castro Santos M H. Fragmentation and Decision: The Case of Fuel Alcohol in Brazil, Paper presented at the Conf. on ProAlcohol, University College London, 24 May 1985. See also her PhD Thesis: Alcohol Fuel in Brazil:An Alternative Energy Policy and Politics, MIT, 1985.

18 Ibid.

19 Barzelay op. cit.p. 60 ff.

20 CEPAL op. cit. p.25.

21 This phase is also called "Third Phase". The reason why I called it Forth Phase is because it appears, for the first time after the events in mid 1983, that the ProAlcool was consolidaded. In August 1983 President Figuereido approved the new goal of $14x10^9$ litres of alcohol to be achieved by 1987/88 harvest. This represented a turning point for the PNA. Its survival was not any longer questioned.

22 Anon. ProAlcool pode producir ate 14 bilhoes de litros. O Estado de São Paulo, 6 Augusto 1983, p. 25

23 Velho P. The Introduction, Generation and Diffusion of Technology in the Brazilian Agro-Industry- The Role of Formal and Informal R&D. MSc Thesis, SPRU, University of Sussex, 1982, pp.31-32.

24 Hall D O.(1985) op. cit.

25 CENAL Relatorio Anual 1984, CENAL 1985,pp.7,8,11, tables, 2,7

26 Gomez da Silva J. Speech at the IIICBE (Third Brazilian Energy Congress) 9-12 October 1984, Rio de Janeiro. He is an important sugarcane grower and highly critical of many of the past alcohol policies.

27 In 1984 Copersucar comprised 70 sugar mills and 5 independent distilleries. It was responsible for 41% of sugar and 45% of alcohol produced in Brazil. The gross value of sales in 1983/4 harvest was $1.7 billion.

See e.g. Copersucar:Uma experiencia Cooperativa, Alcool e Alcoolquímica, 1 (1) 1984, pp. 55-56.

28 Giannetti W A. Capacidade da Industria Nacional para

atendimiento do ProAlcool, Atualidades do CNP, 13 (74) March/ April 1981, pp.46-52.

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30 Anon. Microdestilarias ja rendem como as grandes, Alcool e Alcoolquímica 1 (1) 1984, pp.67-68.

31 As noted above, decentralization is disliked by the central authorities. One reason for lack of support for the small alcohol plant was government fear of losing control of alcohol production. There are already reports that a number of small distilleries are operating clandestinely in remote areas for selling alcohol drinks.

32 Carón D. Social Impacts Associated with the Implementation of Brazil's ProAlcool Programme. Proceed. IV Internt. Symp. of Alcohol Fuels Technology, Guarujá, S.P.1980, pp.733-735.

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35 Borges J M. Programa Nacional do Alcool: Perspectivas para os anos de 1990-2000,1984(Copersucar).

36 CENAL Ralatorio Anual 1984, CENAL 1985, p. 7, table 1.

37 MIC/STI O Desempenho da STI, periodo 1974-1978, Brasilia, 1979, pp. 9 ff.

38 MIC/STI Relatorio de Atividades da SIT, 1979-1981, Brasilia,1981

39 CENAL Acto No. 774/82, 25 June 1982, Anexo 774/82.

40 Monaco L. Coordinador of the PRONAB, Personal Communication, 20 June 1983.

41 Penteado E. Director of the Usina Santa Elisa S.A.,Personal Communication, 20 June 1983.

42 Velho P. Op. cit.pp. 90 ff.

43 See Ministry of Agriculture (MA) Doc. Agroenergia, Diretrices Setoriais, Coordenadoria Especial para Fomento da Biomassa, Brasilia, 1981, pp.9-37.

44 For example, the ProÓleo programme objectives were to plant 0.5 m/ha. of castor oil; one m/ha. of sunflower, and 0.5 m/ha. of peanut by 1986. See Energia-Programa Nacional de Pesquisa, Embrapa/MA, Brasilia, 1983.

45 Netto A O,Yeganiantz L.Embrapa's Food-Feed-Bioenergy Production Systems, Empbrapa/MA 1982, pp. 15 ff.

46 Bautista Vidal J W. Personal Communication, 3 May 1983. He argues that most of the research on biomass was discontinued after 1978. (see note 1-44)

CHAPTER 3 NOTES AND REFERENCES

1 Coronado J. Baixo Rendimiento Prejudica o Pais, Química e Derivados, 19 (210) April 1984, pp. 42-46.

2 Pamplona C. ProAlcool: Impacto em Termos Técnicos-Económicos e Sociais do Brasil, IAA/MIC, 1984, pp. 33 ff.

3 For example the SP114 variety. See STAB January/February 1983, pp. 7-11. See also Da Silva W M. Perspectiva da Cultura da Cana-de-Açucar no Brasil, Anais de II Seminario de Biotecnología Agrícola, Piracicaba-SP, 29-30 August 1984 pp. 47-56.

4 SIT/MIC, Assessment of Brazil's National Alcohol Program, STI/MIC 1981, p. 27, table 4.1

5 Various Speakers during the IIICBE challenged the low productivity figures of the small producers. They argue that an important reason for the campaign against the small sugarcane planter is the vested interest of the large sugarcane growers who try to convince the general public that the large plantations are economically more viable.

6 STI/MIC Previção e Análisis Tecnológico do Álcool, STI/MIC, Brasilia 1980.

7 Ibid. Executive Summary, prepared by the Faculty of Economics and Administration, University of São Paulo.

8 Losses of up to 3.83 ton/ha. are known to occur with mechanical harvesting. In addition the cane contains many impurities which can cause serious problems in the fermentation step of alcohol production. Saccharum 7 (33) July

1984, pp. 31-33.

9 There are enormous variations from harvest to harvest, e.g. data from autonomous distilleries show that productivity has been as high as 80 litres per ton of sugar to 27 litres per ton. Information provided by Planalsucar.

10 Pamplona, op. cit.

11 With regard to the real productivity, I have been told more than once informally, that only the "Usinero" knows the real productivity.For eg., it is reckoned by some experts, that as much as "two billion" litres of alcohol above the official figures were actually produced in 1984.

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16 Carbalho L O. A açaõ do Planalsucar, Saccharum 4 (14) 1981, pp. 19-22.

17 See STAB 1 (3) January/February 1983, pp.7-11.

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18 Brieger F. Implementação de novas lavouras de cana de azúcar em função de ProAlcool, Anais do Simposio sobre Alcool, Secretaria de Indústria e Comercio, ACIESP, No.27, 1980, pp.13-19.

19 Anon. A produção de novas variedades de SP, Boletim Técnico Copersucar, Edição Especial, March 1983, pp.5 ff.

20 Ammirato P W. et.al Biotechnology and Agricultural Improvement, Trends in Biotechnology,2 (3) May/June 1984, pp. 51-58.

21 Knopf U C. Practical Aspects of Biogenetic Engineering in Crops, Outlook in Agriculture 12 (2) 1983, pp.50-54.

22 Crocomo O T."Cana de proveta" Nova técnica auxiliar de melhoramento, Alcool e Açucar 3 (9) March/April 1983, pp.14 ff Crocomo et. al. O Controle da Morfogenese "in vitro" e variação somonal, Anais II Semanario de Biotecnologia Agricola,op.cit. pp.7-12.

23 Lee T S G., Bachi O. Improved rooting of the differentiated shoots from sugarcane callus tissue, Planalsucar, Araras, Personal Communication. Flowering control is important in order to increase/maintain sucrose content of the sugarcane.

24 This is an area which requires greater attention since diseases and pests have caused enormous damage to sugarcane, particulary the "cigarrinha", Mahanarva posticata, which can cause up to 40% losses in the sugarcane, and the "broca", Diatraea sacharadis. A virus against the Diatraea sacharadis was made in 1978 by Pavan and Boncias, and so far it has produced good results. The main difficulty has been finding financial support to market the product.

Pavan D H. Controle Biológico de Pragas, Anais II Semanario de Biotecnologia, op. cit. pp.41-42.

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Ruschel A P. Nitrogen Cycling in Sugarcane, Plant and Soil 67 (198) pp. 139-40.

26 Ruchel A P. Personal Communication, September 1983.

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28 The term Brix is the "sugar concentration" and refers to the cane's sucrose content, technically also called "pol". For ethanol production, in addition to sucrose, reducing sugars (that is glucose plus fructose) present in the cane, must be considered. Thus the total fermentable sugars productivity should be adopted. Productivity of alcohol production should be evaluated in terms of fermentable sugar per hectare. Thus involving quantity and quality.

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Anon. Busca de Altos Teores, Raizes 8 (83) Febraury 1983,pp.32-33.

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33 See UNIDO Workshop on Fermentation Alcohol, 26-30 March 1979, Vienna (Austria)

34 Mello op. cit.

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36 Mini-Usinas de Alcool de Mandioca, Fundação de Tecnologia Industrial (FTI) 1983, p. 17.

37 Mello op. cit.

38 Secretaria de Agricultura e Abastecimento, Plano Indicativo da Mandioca, Campinas-SP. 1979.

39 Normanha E., Lorenzi O J., Personal Communication 23 Sept.1984

40 O Estado de São Paulo, 1 May 1983.

41 Lorenzi O, Monteiro D A. Mandioca como materia prima para a produção de etanol no Brasil, Boletim Técnico No.67, October 1980, p. 19. (Instituto Agronómico de Campinas-SP)

42 Ibid. p.16, pp.57-61.

43 For example, for each litre of alcohol produced are needed 2.7 Kg. of bagasse (50% humidity).Each Kg of bagasse produces 2.4

Kg. of steam.Hence we have 2.8x2.4= 6.7 Kg. of steam. To produce one litre of alcohol requires 6.5 Kg. of steam (this can be reduced to 4.5 Kg./litre) therefore, in theory at least, a cassava distillery can be self-sufficient in energy

44 Embrapa- Centro Nacional de Pesquisa, Milho e Sorgo, Systema Rural de Bioenergia,(undated), pp.3-15.

45 Cesar M A., Delgado A A. O sorgo sacarino na industria alcoolera, Alcool e Açúcar 2 (7) November 1982, pp. 50 ff.

46 Borgonovi R A. et. al. Recomendações para o plantio de sorgo sacarino, Lavoura (84) September/October 1982, pp.38-42.

47 STI/MIC Assessment of Brazil's (..) op.cit. p.22.

48 Biomassa, a Opção Energética da Nestlé, (Report prepared by Miranda D J) Brasilia(undated) pp. 51-59.

49 Embrapa-Programa Nacional de Pesquisa Forestal, Brasilia 1981, p. 19, table 1.

50 Anon. Coque e Alcool da Madeira-Perspectivas da Coalbra S/A., Cutlturas Energéticas 1 (3) September/October 1982, pp.10-13.

51 Antrate Junqueira I, Superintendent of the Planalsucar Technology Development Centre (Araras-SP), Personal Communication 11 September 1984.

52 Coalbra: Alcool e Emprego: O impacto da Produção de Alcool de Cana-de-Açúcar e de Madeira na Generação de Empregos, Cadernos Coalbra-3, Coalbra S/A,1983.

53 Coalbra: Questões Básicas Sobre o Etanol de Madeira, Cadernos Coalbra-2, Coalbra S/A, 1983.

54 STI/MIC Assessment of Brazil's (..) op.cit. p.23.

55 Ibid.

56 Anon. Metanol, o Programa Alternativo da CESP, Alcool e Alcoolquímica 1 (1) 1984, pp.72-74.

57 Abreu R S. et.al. Projeto Etanol da CESP,Mauá Institute of Technology,SP, Personal Communication 15 September 1983.

58 For example the STI/MIC attempted to set up a pilot plant to process babassu nuts, but had to be abandoned when local farmers refused to hand in the whole nut(needed to obtain the oil) because it has many traditional uses.

59 Filho A S. et.al. A Cultura da Mamona e a Substitução de Energia, Proceed. IIICBE. op. cit. pp.1386-1394.

60 Materic V. Substitução de Óleo Diesel, alternativas e viabilidade de produção de diesel vegetal no Brasil,Proceed. IIICBE op. cit. pp.1629-1634.

61 Macedo I C. Considerações Técnicas na Produção de uso do bagaço de cana excedente como combustível,Proceed. IIICBE op.cit. pp.1700-1707.

62 Copersucar, Seminario Sobre Bagaço de Cana, CTC, 7 February 1983, p.30.

63 Ibid. p.18.

64 Ibid. p.19.

65 Anon. Aproveitamento Energético dos Residuos da Agroindustria (..) ,MME/Electrobrás 1983, p.123, table 4.1-XIV.
For example, Papel de Tucumán,Argentina,has set up a plant to manufacture 110 000 ton/year of newspaper printing paper from sugarcane bagasse.

66 Molasses from sugarcane are becoming increasingly important. See e.g. New Scientist 105 (1444) 21 February 1985,p.8.

67 The thermal hydrolysis of bagasse consists in keeping the bagasse in a closed themal system to dilute the cellulosic, hemicellulosic and lignin of the bagasse, to increase the digestibility. See SOPRAL 3 (26) December 1984, pp.15-16

68 E.g. Usina Nova America(Assis,SP) started to produce in 1985 yeasts for animal feed.The yeasts originate from the *Saccharomyces cervisae* used in the fermentation process, which are separated from the stillage through a centrifugal process.See SOPRAL 3 (26) December 1984, pp.20,50

CHAPTER 4: NOTES AND REFERENCES

1 These are my impressions after talking with a large number of people in Brazil.This is, however, a very broad view and refers exclusively to the sugarcane alcohol equipment sector.

2 D'Avila S.G., Head of the Department of Chemical Engineering, University of Campinas (Unicamp),S.P.,Personal Communication, 3 September 1984. D'Avila is also a Consultant of PROMOCET (Agency for the Promotion of Science and Technology Research in the State of São Paulo).

3 Anon. Máquinas e Equipamentos, Exame- Edição Especial, September 1983, pp. 223-227.

4 Anon.Queda de Produção chega ao Límite, Química e Derivados, (Especial guia Geral de Equipamentos) February 1984, pp. 12-15

5 Ibid.

6 See O Estado de São Paulo, 4 September 1983, pp. 4-5., and Folha de Sào Paulo, 18 August 1984, p. 12.

7 Anon. Tecnología Brasileira na Produção de Equipamentos, Alcool e Alcoolquímica, 1 (1) 1984, pp. 64-66.

8 Perecin N. Sales Manager of CONGER S.A, Personal Communication 6 May 1983.

9 Bautista Vidal J W. Personal Communication, 15 May 1983 and 18 July 1983.

10 Aguiar Puppo A M., Executive-Director of ABDIB, Personal Communication.

11 Negri B. Um Estudo de Caso de Industria Nacional de Equipamentos: Analise de Grupo Dedini (1920-1975), MA Thesis,

Instituto de Filosofia e Ciencias Humanas ,Unicamp, 1977, pp. 148 ff.

12 Cerrao Fiho A M, Director of SUCRAL- Assesoria de Projetos para Acucar e Alcool, Personal Communication, 4 May 1983.

13 See for example Negri op.cit.

14 O Estado de São Paulo, 27 September 1983, p. 35.

15 Negri op. cit. p. 363 Table IV-13. The Dedini Group comprises 10 companies directly concerned with the sugar and alcohol equipment sector. These include: M.Dedini S A, Codistil, Dedini S A Siderúrgica, Açúcar e Alcool São Luis, Dedini Agropecuaria, Destilaria São João, Dedini S A Máquinas e Sistemas, Dedini Equipamentos Eletricos, Dedini Refratorios, and Dedini Comercial.(Ref.Company Information)

16 Anon. Quem faz o que para o Alcool, Química e Derivados, 16 (174) Jan/February 1981, pp. 26-40.

17 Guidoboni G Engineering for an economic fermentation, Chemistry and Industry, (12) 18 June 1984 p. 443. For conditions of International Bidding see Doc. "Portaria Interministerial" No. 118 of 22 June 1982.(Decree-Law No.1938 of 10 May 1982, Article 2). The World Bank loan of $250m was made to finance 40 to 50 distilleries (to add a capacity of 1.5 to 2 billion litres year) with the condition that Brazil should allow foreign involment in the ProAlcool.

18 Scheaffer A. Managing Director of MAUSA SA. Personal Communication, 11 July 1983.

19 Although Brazilian firms have sucessfully won most contracts, many firms are turning to foreign Know-how for their most

sophisticated technological processes. A good example is the Biostil process, which Dedini bought from Alfa-Laval of Sweden. Other processes include continuous fermentation and new distillation processes. Not all industrialists in this sector like to admit that new processes are being acquired from abroad.

20 Sercovich F C , op. cit.

21 Wright op. cit. pp. 216 ff.

22 According to Decree No. 85 698 of 4 February 1981, issued by the Vice-Presidency a "Microdistillery" is defined as a plant with a maximum capacity of 5000 litres/day of alcohol; and a "Minidistillery" that with a capacity of between 5000 to 30 000 litres/day. Medium distillery 60-90 000 litres/day; large distillery over 120 000 litres/day.

See. e.g Secretaria de Ciéncia e Tecnología of Minas Gerais ; Conceito de Micro e Minidestilaria de Alcool-Política de Implantação. See also Yassu F As Microdestilarias, O Estado de São Paulo, 11 March 1984.

23 Velho P. Technological Aspects of ProAlcool, Paper Presented at the Conf. on the Brazilian PNA: Issues and Prospects, University College London, 24 May 1985.

24 Varaschin V M, Adams R I, Microdestilaria-Uma Estratégia para o Desenvolvimento, Proceed. IIICBE. op.cit. pp. 1584-86. This study desmostrated, according to these authors, that employment increased by 31.11% and family income by 9.9%

25 For example, Embrapa's research team who has been investigating the use of diffusershas reported an increase in

yield of near 90%. See Gonçalves Texeira et.al.. _Produção de alcool etílico em microdestilaria pelo processo de difução._ IIICBE. op. cit. pp. 1587-1593.

26 Corsini R. School of Engineering, University of São Carlos, S.P _Personal Communication 22 September 1983_.Almeida L.,Director of Dpt. of Rural Technology, ESALQ, _Personal Communication, 8 September 1983;_ Adams R I, IEPE (Instituto Estudos e Pesquisas Economicas, UFRS (Federal University RS , Porto Alegre). _Personal Communication 21 September 1984._

27 I reached this conclusion after talking with a number of industrialists in this industry- e.g.Dedini, Zanini, Mausa,etc But not all agree with this term.

28 Oliveiro J L. _Tecnologias da Dedini na Produção de Alcool,_ I Seminario de Tecnologia Industrial de Produção de Alcool, SIT/MIC 8 August 1984.

29 During my visit to the Codistil I could not get real figures of the cost of Biostil on the ground that the plant was in a experimental stage. Outside critics have argued that Biostil costs are between 25-30% higher than the conventional plant of the same capacity. However the real cost is known to Dedini only.

30 The FLEGSTILL process, developed by Dedini in 1982, is also an important innovation but much more within the traditional design. The most important characteristics include lower steam consumption, 1.4 kg. steam for litre alcohol, against 3.4 Kg/l in the conventional distillation columns; 30-40% lower water consumption; 60% reduction of component parts of the distillation system, etc. Oliveiro _op. cit._ p. 27.

31 Zanini Research and Development Department. Zanini research team also calls this new technology "transitional technology" which will form the basis for the development of more advance design.

32 Dedini, Company Information. See also Química e Derivados 17 (196) December 1982, pp. 24-28.

33 COSINOR (Companhia Siderurgica do Nordeste) with technical assistance from the French company Speichim has also introduced a novel system for distillation which consumes 2.44 Kg of steam per litre of alcohol produced from wine of 7.5 GL at 85 °C and stillage with 0.02 % GL of alcohol content. This is ten times less than a conventional distillery. See. Química e Derivados 17 (196) December 1982, pp. 30-32.

34 My impression is that a good number of industrialists, particulary small equipment manufacturers, consider it to be cheaper in many cases to import the technology rather than to wait for the Brazilian firms to produce new designs.

35 Thurston C. Brazil's Route to Energy Independence, Chemical Engineering 92 (6), 18 March 1985, pp. 20C-20F.
See also an interview given by the President of Petrobras to the O Estado de São Paulo 29 May 1984, p. 34.

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37 D'Avila S.,Aperfeiçoamentos Tecnológicos na Produção de Alcool, _Atualidades NCP 15 (86) Jan/February 1984_, p. 14.

CHAPTER 5 NOTES AND REFERENCES

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2 Velho (1985) op. cit.

3 For example Copersucar is now introducing juice-treatment technology from Australia.See Sobral M O. Centro de Tecnologia Copersucar, STAB 2 (6) July/August 1984, pp. 55-66.

4 Bjurstram J. Biotechnology, Chemical Engineering 92 (4) February 1985, pp. 126-158.

5 Klass D. Energy and Synthetic Fuels from Biomass and Wastes; Handbook of Energy Technology and Economics;(R A Meyers Editor), John Wiley&Sons (1983) p. 780.

6 Bernard D D. Hall D O. Energy from Renewable Resources, Biotechnology (H Dellweg Ed) Verlag Chemie, Basel, (1983) Vl. 3 Chapter 4 p. 600.

7 Kosaric N. et. al. Ethanol Fermentation, in Biotechnology op. cit. Chapter 3a. p. 270.

8 Anon. Fermentation scale-up. New Scientist 104 (1433) 6 December 1984, p. 26.

9 Klass D L. Energy from Biomass Wastes, Bio/Technology 2 (5) May 1984, pp.434-440

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kept open to eliminate impurities and to reduce investment. Other argue that the greater alcohol production justify the utilization of closed tanks.

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12 Almeida Lima U. Director of Dpt.of Rural Techology, ESALQ, Personal Communication, 8 September 1983.

13 Vianna Amorin H. Director of FERMENTEC. S/A. Personal Communication, 19 September 1983.

14 Vianna Amorin H. Progressos na Técnica de Fermentação Alcoolica no Brasil, Alcool e Açúcar 2 (4) May/June 1982, pp. 50-54.

15 There are not many technical details available, but it seems that the process reduces, considerably, the need for chemical antifoam agents, from 60 Kg/day to 20 Kg/day. This process is used in the distillery BAISA S/A, Popu, S.P., See SOPRAL Informativo 3 (26) December 1984, p. 17.

16 Vianna Amorin H. Personal Communication 19 September 1983.

17 Copersucar, Internal Publication.

17 Bis See also Velho (1985) op. cit.

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October 1980, pp. 139-141.

19 Tavares F A. Genetic Engineering for Alcohol Production: Proceed. "Simposio Internacional de Engenharia Genetica, Piracicaba, S.P. 6-10 December 1981, pp.3-6.

20 Kosaric N. et al. op. cit. p. 261.

21 Vergara W. Improving the Scenario for Ethanol Processes, Proceed. IV Inter. Symp. Alcohol Fuels. op. cit.pp.143-150

22 Sineriz F. Microbial Fuel Production, Impact 32 (2) April/June 1982, p. 172.

23 Essar K, Karsch T. Bacterial Ethanol Production: Advantages and Disadvantages, Process Biochemistry 19 (3) June 1984, pp. 116-121.

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26 Codistil-Constructora de Distelarias SA, Piracicaba, S.P. Company Information.

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Margulis S. Environmental Impacts of the ProAlcool, Paper presented at the Conf. on the Brazlian National Alcohol Programme:Issues and Perspectives, University College, London

24 May 1985.

Costa Reviero C. A Questão do Vinhoto Revisada, Engenharia Química 6 (1/2) March/June 1982, pp. 12-17.

28 STI/MIC, Novas Tecnologias de Produção de Álcool com Redução do Volume de Vinhaça, Brasilia, July 1983.

29 See SOPRAL Informativo 3 (25) July/August 1984, p. 30.

30 Sá de A et. al. Fabrição de Alcool sem vinhoto, Engenharia Química 6 (1/2) March/June 1982, pp. 51-58.

31 Zarpelon F. Redução do Volume de vinhoto, STAB 1 (2) November /December 1982, pp.28-35.

32 Almeida da Gloria N., Orlando J. Aplicação da vinhaça como Fertilizante. Bol. Técnico Planalsucar 5 (1) January 1983 pp. 6-9.

33 Barreto de Menezes J T. Biotechnology to Solve the Problem of Stillage Disposal, Industrial Biotechnology Wales 4 (1) January 1985, pp. 4-8.

34 For example, Margulis estimates that the investment required to apply stillage (trucks, equipment etc.) for an annexed distillery is $125 000 and $270 000 for an autonomous distillery. The cost of buying chemical fertilizers is about $200 000 (at 1982 dollars). See Margulis op. cit.

35 E.g. The "Usina ADALCOOL" located in S.P. has installed a biogas plant with capacity for 1400 m3/day. It uses technology designed in the IPT. The Biodigestor is of the Up-Flow type to take maximum advantage of the bacteria present in the stillage. This can reduce pollution by 80%. See SOPRAL Inform. 3 (26) December 1984, p.14.

36 Barreto de Menezes op. cit. p. 6.

37 Barreto de Menezes J T. Quoted in Kosaric N et.al. op.cit. p. 285.

38 Kosaric N. et.al. op.cit. p. 286.
See also Henrique da Silva G, Coutinho P H A. Cocimento Continuo de pasta de Amido para a Produção de Etanol, Proceed. V Inter.Symp. of Alcohol Fuels. op. cit. pp.71-75.

39 Nothenberg M. Mercado Crese na rota da mandioca, Química e Derivados March 1981, pp. 24 ff.

40 Anon. Algums exemplos da aplicação dos enzimas da Pfizer na produção de Glicose e Alcool, Boletim Técnico Pfizer, January 1982, pp.2-5.

41 Anon. Novo Industri e Biobras assinam Contrato, Saccharum 7 (33) 1984, pp.20-21.

42 Coalbra, Produção de Etanol de Madeira, Cadernos Coalbra-1 Brasilia 1983, pp. 113 ff.

43 Lloyds A. French push ahead with biomass conversion, New Scientist 102 (1407) 26 April 1984, p. 21.

44 Husain H. A Critical Review of Ethanol From Cellulose Technologies, VI International Symposium of Alcohol Fuels Technology, Ottawa, Canada,21-25 May 1984, pp.2/154-59

45 Dzenis A, Mc Nab J. Commercial Recovery Processes for Ethyl Alcohol, Ibid. pp.2/218-231.
For example, by using an integrated distillation unit which re-use heat, the energy requirements can be reduced by 62% of the conventional process. Use of molecular sieve dehydration in place of the second azeotropic distillation step reduces

the energy requirements to 58% of the traditional process; and adding mechanical vapour recompression to the first stage distillation, and using molecular sieve dehydratation will further reduce, according to tha authors, the energy requirement to 36% of the traditional process.

CHAPTER 6 NOTES AND REFERENCES.

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2 See Rothman et.al. op. cit. Chapter 5, pp.89-104. See also Encyclopedia of Chemical Technology, Supplement volume, Kirk-Othmer, John Wiley 1980, pp.1-42. This is a very good description of alcohol fuels.

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4 Rosillo-Calle F. Fuel Ethanol in Brazil and the Implications for Control of Lead Additives in the EC Countries, 3rd.Energy from Biomass Conf., Venice, Italy, 25-29 March 1985.

5 Herman M J, Trends in the Implementation of the USA Alcohol Fuels Program:The Growth of State Labeling Requirements and Automobile Warranty Restrictions on Alcohol Fuels, Proceed. VI Inter. Symp. of Alcohol Fuel Technology, Ottawa, Canada, 21-25 May 1984., pp. 287-293.

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7 Hamber M. The Alcoholic car of the Future, New Scientist 102 (1406) 19 April 1984, p. 24.

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13 Severo C, A Política dos Transportes no Brasil 1975-1985, Speech given by the Secretary of State for Transport to the

Higher School of War on 10 July 1984.

14 The concentration on road transport is also due to the enormous vested interests of the automobile industry which considers any alternative to road transport in Brazil as "unrealistic."

15 I learned during the IIICBE,October 1984, that the Government was preparing legislation to reduce dramatically vehicle production (particulary passenger cars) to cut oil imports, unless the automobile industry was prepared to accept the alcohol car.

16 Aguiar Puppo, Executive Director of ABDIB,Personal Communication September 1983.

17 Bautista Vidal, Personal Communication September 1983. This is the view of many Brazilian Officials I have talked to.

18 Fernandes Danna, SIT/MIC, Personal Comm. 24 September 1984.

19 See O Estado de São Paulo, 9 July 1984. SOPRAL Inf. 3 (25) July-August 1984, p. 26.

20 CENAL, Relatorio Anual 1984, CENAL 1985,p.37,table 41

21 This is my view after talking with members of ANFAVEA in Sao Paulo. It is difficult to find exact figures since the companies do not disclose such information easily.

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23 Aguiar Puppo op. cit.

24 It is difficult to define a "generation of alcohol cars" but it may be defined as important changes that differentiate it from the previous one.

25 Kajimoto Z, et. al. Corrosion Performance of Metallic Coating in Ethanol Fuel (..).Proceed. VI Symp. Alcohol, op. cit. pp.1-225-231.

26 STI/MIC, Escolha Certo, 1984.

27 Goodrich R S.Alcohol Cars in Brazil's Future: A Technological Forecast,Proceed. V Internt.Symp.Alcohol. op.cit.p.849. This figure seems too high for alcohol. However the IPEI (Inst. of Research and Industrial Studies) in S. B. do Campo, S.P. has developed a pick-up "Caure" capable of doing 20 Km/l on alcohol. This has been possible by reducing the weigh by 70% using synthetic fiber materials. See O Estado de São Paulo 5 September 1984, p. 23.

28 Anon. O Óleo diésel tem Alternativas, Petro e Química, December 1981, pp. 116-117.. Nogreiros Fonseca M A, SOPRAL-3 Avaliação de Caminhões e Tratores a Álcool, p. 25.

29 This information has been compiled from MBB sources and from STI/MIC.

29bis About 3000 trucks originally running on diesel have been converted to alcohol.Of the 34 000 tractors used in the sugar cane and alcohol farms, 500 now run on alcohol. It is estimated that about 90% of these tractors could be run on alcohol with a conversion cost of $7.5 m.(1983).This could save 4% of oil imports.See Hall D O.(1985) op. cit. p.10

30 Bindel H H W, Implementation Experiences with MWM PID Engines Burning Alcohol as main Fuel, Proceed. VI Inter. Symp. Alcohol. op. cit. pp.1-56-62.

31 There is a programme called "Fundo de Barril" whereby the

production of diesel per barrel of oil would increase from 24% in 1980, to 35% in 1985 and 40% from 1985. The production of gasoline would be reduced from 28% to 22% and 18% respectively See Ventura L. SOPRAL-3 op. cit. p.82, figure 11.

32 See Circular No. 096/82 of 3 September 1982 of the "Sindicato da Indústria de Fabricação do Álcool no Estado de S. Paulo.

33 Celestino Rodriges S E. Substituição do Diesel, Culturas Energéticas, 3 (7) August 1984, pp.28-38.

34 Mesquita de Siqueira L E, C T A, Insituto de P&D, Divisao de Mecánica, Personal Communication, August 1983.

35 Bindel op. cit.

Anon. O Desenvolvimento da "injeção piloto" para o uso de alcoois em motores Ciclo Diesel, STAB 1 (4) March-April 1983, pp. 17-23.

36 Aguiar A C, Comportamento dos Esteres Metílicos de Óleos Vegetais em Motores Ciclo Diesel-Situação Atual dos Experimentos com Esteres de Óleos Vegetais, Proceed. VI Annual Symp. of ACIESP, Vl. 2, pp.108-112.

The production of vegetable oils in 1980, was 3.8 billion litres, consumption 1.1 bn./l. and exports 2.7 bn./l. The cost was 1 ton of petrol= $253

1 ton soyabean = $542

1 ton palm oil = $685

37 Castro Villar S. et. al. Considerações sobre a Utilização de Oleos Vegetais para Fins Energéticos, Proceed. IIICBE op. cit. pp. 1158 -67.

38 Maretic V, Substituçao de Óleo Diesel, Alternativas e

Viabilidade de Produção de Diésel Vegetal no Brasil pelo processo CEPED, IIICBE op.cit. pp. 1629-1634.

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40 Pischinger G H.et.al.Results of Engine vehicle Tests, with Methyl Ester of Plant Oils as Alternative Diesel Fuels, Proceed V Inte. Symp.Alcohol Fuels,Auckland, N.Zealand, 13-18 May 1982, pp.374-383.

41 For example the research team of UNICAMP has developed a new catalyst which allows for the transesterification of vegetable oils with ethanol in the presence of up to 10% water.Personal Communication.

42 See Martorano Ventura L. et.al. First Results with MBB DI Diesel Engines Running on Monoesters of Vegetable Oils, Intern. Conf. on Plant and Vegetable Oils as Fuels, 2-4 August 1982, Fargo, N. Dakota, USA.

43 MBB, Company Information

44 "Alcooldiesel" is a blend of hydrated alcohol and diesel oil. According to its inventor, Alfredo Rafael Alcantara, it does not pollute and can make 8.6 km/l against 9 km/l of diesel in light vehicles(unloaded).It is easy to produce and can be blended with any veg. oils.The research was suppported by the CNP. It is being patented as an additive.Few details are known of the chemical composition of such additive. See. O Estado de S. Paulo 8 June 1985, p. 28.

45 STI/MIC, Utilização de Óleos Vegetais em Motores Diesel-

Programa OLEG-1, STI 13 May 1983 (Internal document). The STI is studying various alternatives, in both veg. oils and blendings proportions.

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48 See SOPRAL Informativo 3 (26) December 1984, p. 40. Celestino Rodrigues E. Solução Energética, op.cit. p.209

49 Martorano Ventura, Chief of the Dpt. Experiencia de Motores MBB, Personal Communiction, 15 August 1983.

50 IQT, Company Information. The THFNA is obtained from furfural in two stages: (i) formation of furfuric alcohol through the use of catalysis (ii) hydrogenization. The production of THFN from the THFNA is through a nitrogenization process in reaction with concentrated nitric acid, in conditions of ideal temperatures to avoid the formation of too many by-products.

51 Most of these additives under investigation are quite expensive.With regard to the THFN the IQT estimates for producing 1000 ton/year and 3000 ton/year from sugarcane

bagasse, are \$3.5 m.(or \$1.45/kg in the first case) and \$5 m (or \$1.13/kg. in the second case). IQT, Company Information As for the technology, there exist four main processes in a commercial scale: (a)Quaker Oats (USA); (b) R. Ceseker Wyss, (Swedish);(c) L.Alba (Mexico); (e) Codetec (Brazil).

52 Nery E. Muitos Planos e poca ação, SOPRAL-3 op.cit.pp.9-12

53 CENAL Relatorio January/February 1984, p.17, tables 18, 19.

54 Ibid pp.17, 18

55 Anon.So agora álcool atrae mas Mercado, Viçào 32 (46) 14 November 1983, pp. 56-57.

56 SOPRAL Informativo 3 (26) December 1984, p. 44.

57 CENAL Relatorio January/February 1984

58 Quoted in Nery E. op. cit. p. 12.

59 Aguiar A C. op. cit. The consumption given by this source is:
0.63 l/km. ten tons Otto-Cycle (alcohol)
0.83 l/km. 52.7 tons Diesel
0.83 l/km 52.7 tons (alcohol plus additive).

60 Companhia Brasileira de Tratores (CBT), SOPRAL-3 op. cit. pp.145-171.

61 CENAL ProAlcool, Relatoria, January/February, pp. 17-18.

CHAPTER 7 NOTES AND REFERENCES

1 See e.g Rothman et. al . op.cit. p.2. See also Biotechnology: A Dutch Perspective (J H F van Apeldoorn Editor), STT Publications 30, Delft University Press 1981, Chapter 6, pp. 119-155.

2 See O.T.A, Commercial Biotechnology, An International Analysis, Washington D.C., USA Congress O T A, January 1984, Chapter 9, pp. 237-250.

3 An example of the possibilities offered by Biotechnology is illustrated by fungus 'Phanerochaete chrysosporium' which degrades wood.This could be used to extract large quantities of valuable chemicals such as aromatics, cellulose, and sugar from plant and vegetable materials. Enthusiasts regard this fungus capable of revolutionizing the chemical industry. See Milgrom L, Ligninase: Biotechnology's new money spinner? New Scientist 106 (1456) 16 May 1985, pp. 16-17.

4 Anon. Energy from Biological Processes, O T A. op. cit. Chapter 12, pp. 227-234.

5 Ng T K, et. al. Production of Feedstock Chemicals, Science 219 (4585) 11 February 1983, pp. 733-739.

6 There exists a large literature on the technical aspects of production of chemicals from biomass, and possible biotechnological implications. See e.g. Clements L D, et al. Chemical from Biomass Feedstocks, Chemical Engineering Progress 79 (11) November 1983, pp. 59-62.; Lepkowski W., Developing Countries: Challenge for Chemists, Economists;

Chemical Engineering News 61 (33) August 1983, pp.6-12.

Sheppeard W J, Lipinsky E S. Chemicals from Biomass, 2nd. EEC Conf.: Energy from Biomass,(Strub A, Chartier P,Schlesser E, Editors), Applied Science Publications, 1982, pp. 63-71.

World Bank, Alcohol Production from Biomass in Developing Countries, World Bank, September 1980.

7 This table has been compiled from different sources.(Rothman et. al. and Papers from the 2nd Brazilian Congress of Alcohol-chemistry, September 1983, Recife,PE).

8 Eswaran V V, Alcohol-based Chemical Industry, Chemistry and Industry (24) 18 December 1982, pp. 967-68.

In 1982 there were in India 127 distilleries with a total installed capacity of 732 million litres/year. The alcohol is mostly for consumption in the chemical industry.

9 Brazilian firms are showing a strong interest to demonstrate their know-how on alcohol-based alcoholchemistry technology to capitalize on the international market possibilities. They are participating, e.g., in Japan's Expo'85 (from March to Sept 1985) with a stand to show their capabilities in this field. Abiquim Noticias 7 (32) January/February 1985.

10 The Saudi Arabia has invested over $10 billion in the petrochemical sector; many of these projects come on-stream from 1985. The main projects include 1.25 m. ton/year of methanol; 1.6 m. ton/year of ethylene; 0.59 m. ton/year of polyethylene, etc.. See Abiquim Noticias 6 (31) October/November 1984.

11 Abiquim Noticas 5 (25) September/October 1983

12 Abiquim Noticias 6 (28) April/May 1984. The State control of the Petrochemical industry increased from 22% (1969) to 32.6% (1983).The domestic private participation increased from 16% to 41.9% in the same period.

13 This has been due to a deliberate policy of transferring capital to the control of the State and private sectors.

14 CENAL Relatorio Anual 1984, CENAL 1985, p.22, table 23.

15 Saravia J. O Rapido crescimento da Alcoolquimica no Brasil, Alcool e Alcoolquimica 1 (1) 1984, pp. 79-82.
The most important alcoholchemical companies are: Salgema which represents 39.7% of the total alcohol consumption in this industry; Rhodia with 22%; Union Carbide with 14% and Elekeiroz-NE with 9.2%. CENAL Relatorio Anual 1984, CENAL 1985, pp. 22-23.

16 Texeira F L S, Recent Development of the Ethanol-Chemical Industry in Brazil, Paper presented at the Conf. on ProAlcool, University College London on 24 May 1985.

17 Abiquim Noticias 7 (32) January/March 1985, p. 5.

18 CENAL Relatorio Anual, op.cit. p.24.

19 See. Rothman et.al. op.cit. pp.74-75, table 4.1; Texeira op. cit.

20 Sanefuji T. Alcoolquímica no Contexto da Indústria Química Brasileira, 2nd. Brazilian Congress of Alcoholchemistry, Recife, September 1983, p. 8

21 For example Claudio Moura. J, (Chem.Eng. Dpt. University of Campinas, SP) argues that Brazil has capability and a technological leadership in alcoholchemistry technology.(Personal

Communication 15 April 1983).

Cunha P., Managing-Director of Oxiteno also argues that Brazil has such capability altough he admits that this technology is far behind that of petrochemical processes.Most research is being confined to improve existing alcoholchemical processes rather than new ones. Personal Communication 20 July 1983.

22 Mario Mendez, Chem Eng. Dpt. Univer. Campinas. Personal Communication 16 April 1983. He argues that Brazil is far from possessing an efficient alcoholchemistry industry.

23 Alcoolquímica Informações 1 (10) October 1983, p. 58.

24 Texeira op. cit. For a technical description of the main ethanol-based chemical processes, see Rothman et.al.op.cit. pp.82-86; Maoura Campos M. O Álcool como substituto do petróleo na indústria química, Problemas Brasileiros, August 1981, pp. 28-39. This is an excellent paper which describes all main ethanol-based chemical processes.

25 D'Avila S G. Uso do Etanol na Indústria Petroquímica, Engenharia Química 4 (2) July 1980, p. 15, table 5.

26 Fucks Calil S. Technical Coordinator of Abiquim, Personal Communication 4 September 1984.

27 Unger T. Managing-Director of Rhodia, Personal Communication 21 September 1983. According to Unger this is one of the most difficult obstacles to overcome. The consolidation of this industry depends very much on improvements in the agricultural and industrial phases of alcohol production.

28 Not everyone would agree with this conclusion however. Some critics of the PNA argue that new natural gas discoveries

pose a serious threat to the alcoholchemical industry because the high cost of raw material (alcohol).

29 Unger T. Contradições da Alcoolquímica, 2nd. Brazilian Congress of Alcoholchemistry, op. cit.

30 Anon. Nafta Sobre. O que fazer com ela?, Abiquim Noticias 6 (30) August/September 1984, p. 5.

31 See e.g. STAB 2 (5) June 1984, pp. 27 ff.

32 One of such projects is Coperbo's $115 m to produce vinyl monomers, planned to enter operation in February 1986. Salgema and Union Carbide also argue that the CNP meassure would make uneconomic their exports of Dichloroethene (DCE) Abiquim Noticias 7 (32) January/March 1985, p. 5

33 For a more detailed account of the cost of alcoholchemical products, see Sanefuji T. op.cit.,particulary pp.14-29.

34 Unger T. Quoted in Journal da Petroquimica 1 (2) October 1984

35 See e.g. European Chemical News(ECN) Specialty Chemicals, Chemiscope, May 1985. ECN Special Supplement.

36 Journal de Petroquimica 1 (2) October 1984, p.3.

37 Souza Antunes op. cit. p. 86, table 2. See also Alcoolquimica Informacoes 1 (2) December 1983, p. 69.

38 "Sucrochemistry" is a term proposed by the American H. Hass in the 1950s, then President of the Sugar Research Foundation Inc. to define a sector of the chemical industry which includes all sucrose and by-products. In the case of Brazil, this term refers to sugarcane-based chemical industry e.g.bagasse, cane juice, molasses, socrose, and products derived from "natural sugars". See Khan R. Some Fundamental

Aspects of the Chemistry of Sucrose. In Hickson J L. Ed., American Chemical Society 1977, Chapter 4, pp. 40-59.

39 This information is based on a report prepared by Promon Engenharia S/A RJ. for the State of Pernambuco, on the potential of the Sucrochemical industry. See Anon. Pernambuco avalia seu potencial sucroquímico.*Química e Derivados 16 (184) December 1981*, pp.24-32.

40 *Ibid.*. See also Anon. Produção de derivados sucroquímicos:Uma nova perspectiva para o Brasil no mercado mundial. *Alcool e Açucar 2 (3) March 1982*, pp. 56-57.

41 Japan is the leading country in sucrochemistry "specialty products" technology. In 1979 Japanese industry manufactured $1.1 billion of sucrochemistry products; followed by the USA with $742 m.(in constant dollars).Other countries with a sizeable sucrochemistry industry are South Africa and Cuba. Anon. Sucroquímica no Mundo, *Química e Derivados, 16 (184) 1981*, pp. 30-32.

42 Cunha G A P. *Bases para a expanção da Indústria Alcoolquímica,* First Brazilian Congress of Alcoholchemistry op. cit.

43 Sanefuji T *op. cit*. See also Ribeiro Sandrini F A. *Alcoolquímica no Contexto da Indústria Química Brasileira,* 2nd.Brazilian Congress of Alcoholchemistry op. cit.

<u>CHAPTER 8: NOTES AND REFERENCES</u>

1 See e.g. <u>Financial Times Survey: Brazil, 5 November 1984</u>, pp. 2-8.

2 See House R. Land of the Tormented ones, <u>South, May 1984</u>, pp.12-14. <u>Financial Times 10 November 1983</u>, p. 23.
On the political problems see e.g. Borges da Fonseca H., Refleçôes sobre a crisis Brasileira; <u>Problemas Brasileiros 29 (347/348) February/March 1984</u>, pp.25-34.

3 See e.g. Whitley A. <u>Financial Times, 10 July 1984</u>, p. 4.
<u>The Eeconomist, 7 July 1984</u>, pp. 35-36

4 On the political problems caused by Tancredo's death, see
<u>Veja (865) 3 April 1985</u>, pp.20-31
<u>Veja (866) 10 April 1985</u>, pp. 20-30
<u>Veja (867) 17 April 1985</u>, pp. 20-33.
<u>Financial Times 27 March 1985</u>, p. 4
" " <u>12 April 1985</u>, p. 22
" " <u>23 April 1985</u>, p.24
" " <u>10 May 1985</u>, p.6
<u>The Guardian 23 April 1985</u>,pp. 6, 20, 21.

5 See Whitley A. <u>Financial Times, 24 June 1985</u>, p.2
Rocha J, <u>The Guardian, 9 July 1985</u>, p. 21

6 Whitley A, <u>Financial Times 29 May 1985</u>, p. 22.

7 <u>O Globo, 6 June 1985</u>, p. 24

8 <u>Financial Times 17 June 1985</u>, p. 3
<u>Financial Times 23 July 1985</u>, p. 4

9 CENAL, ProAlcool. Avaliação Social de Projetos; CENAL, August 1983; World Bank: Brazil, Alcohol and Biomass Energy, Washington D.C. April 1981; Borges J.M. Desenvolvimento Económico, Política Energética e Alcool, Copersucar, December 1980; Homen de Melo F. Pelin E R, As Soluçoés Energetícas e a Economia Brasileira, Hucited,(SP), 1984.

The methodology used differs considerably from one author to another. The most consistant and sophisticated method, in my view, is the one used by CENAL that is based on the World Bank but which has been further elaborated by ASTEL-Assessores Tecnicos Ltda., headed by Professor Almeida Magalhaes of the UFRJ. The two main approuches are (a) macroeconomic. This consists in the analysis of all major costs (social and private) of the main sugarcane growing areas as a whole rather than by single projects. (b)microeconomic, which considers the social cost of single projects in details.Because the large number of parameter involved, it is a complex issue which cannot be given full treatment here. For details see de above document (CENAL 1983) and the National Economic Profitability of Alcohol Projects in Brazil: Appraisal Criteria, CENAL/MIC 1981

10 CENAL Relatorio Anual, CENAL 1985, p. 39, table 44.

11 Geller op. cit.

12 Ibid

13 Ibid

14 CENAL (1983) op.cit.The principal assumptions of this analysis include: interest rates on capital investment increased by a factor of 1.67 to 2.33 to remove government subsidies

(equivalent to real interest rates of 6-14%), exchange rates increased by a factor of 1.25 to 1.50 due to overvaluation of the cruzeiro; and direct labour valued at 0:5 to 0.65 times its actual cost due to social benefit of job creation.

15 Geller op. cit. Borges J M, (1980), op. cit.

16 Borges J M, Oferta e Custos de Produção de Alcool no Brasil, Proceed. IIICBE op. cit. pp. 1539 ff., table 3; Borges J M, Programa Nacional de Alcool: Perspectivas para os anos de 1990-2000, Copersucar April 1984 (unpublished)

17 Borges J M, ProAlcool, Economic Considerations about Brazilian Alcohol Programme. F.O. Licht's International Molasses Report, (Ed. H Ahlfeld) 20 (15/16) October 1983, pp. 141-147.

18 Homen de Melo F, The Brazilian Energy Policy and the Alcohol Programme, Paper presented at the Conf. on the Brazilian PNA, University College, London, 24 May 1985.

19 Rosillo-Calle F. Brazil a Biomass Society, in John Wiley Energy from Biomass Series (Forthcoming)

20 These estimates are based on the "social price", that is, they reflect the opportunity costs for society as a whole. For more details see Homen de Melo op. cit. table 1.

21 Motta R S, ProAlcool: A Social-Cost-Benefit Study, Paper presented at the Univer. College, London, op.cit. The reason for choosing SP and GO is because the first is the most important sugarcane producer and the second because it is expected to become an important sugarcane producer in the near future.

22 These estimates are based on the assumption that oil prices will

decline in real prices until 1986, and then to increase by 3.3% annually until 1990. Motta op. cit.

The World Bank projection for oil prices are $29.5 for 1985; $25.9 (1986); $29.5 (1990); $36.1 (1995). Quoted in Motta, op. cit.

23 See Santiago R L, The Making of a New Liquid Fuel: The Brazilian Alcohol Programme, Workshop in the Economics of Interfuel Substitution in LDCs, Imperial College, University of London, 19 April 1985. His argument is that it made economic sense to produce alcohol during the early years of the PNA because the price of sugar was very low. But with the creation of autonomous distilleries the real cost of alcohol is much higher.

24 Interview given by Uekis, President of Petrobras, to O Estado de São Paulo 29 May 1984, p. 23. To give an idea of the price composition of gasoline, the following figures would be useful: Price of one l/gasoline to the consumer (2 May 1985) Cr$ 2170 of which:

raw material cost	Cr$ 895.63
Cost of unifying price	Cr$ 52.09
Resale(Petrol stations)	Cr$ 48.69
Distribution cost	Cr$ 162.96
Taxes	Cr$ 162.83
Refining cost	Cr$ 410.65
Overcharges to pay for other derivatives	Cr$ 437.15

(the figures correspond to one litre of gasoline).See Journal do Braisl, 2 May 1985,p.17

25 For example "Ultrafertil", a subsidiary of Petrobras, and the main supplier of raw material for the fertilizer industry, received the naphtha at Cr$ 123 litre while the price for other firms cost (May 1985) Cr$2630. Other example is Copene, also a subsidiary of Petrobras, which paid Cr$ 570 litre. See Journal do Brasil 2 May 1985, p.17.

26 Almeida Costa O, Considerações sobre os Preços do Alcool e dos Derivados do Petróleo, Atualidades CNP, 15 (83) July/August 1983, pp. 24-26. (I ignore the exact amount of the subsidies). See also Política de fixação de preços dos derivados de petróleo e do alcool, SOPRAL 1983.

27 See Interview by Lacerda Biagi (millowner) to O Estado de São Paulo 27 May 1984,

28 A further complaint of many industrialists against some critics is that, they argue, full credit is not given to the ProAlcool contribution to GDP, and to real cost of the imported oil. See Lamartin Navarro Junior, Interview to the O Estado de São Paulo, 23 May 184.

29 In June 1983 Brazil paid $30 per barrel of imported petrol and sold the surplus of gasoline at $33.46 FOB.This according to Almeida Costa was benefitial to Brazil. Almeida Costa O. Política de Preços de Petróleo e Derivados, Atualidades CNP 15 (83) July/August 1983, p. 11

30 CENAL Relatorio Anual, CENAL 1985, p. 29, table 31.

31 For further details see Pires Rodrigues A J and Araujo J L R. Limites ao Papel do Alcool na Política Energética, in Energia e Crisis op. cit. pp.105-120.

32 See e.g. Chambers R S, et al. Gasohol, Does it or Does it not Produced Positive Net Energy ?, Science 206 (4420) 1979, pp.789-95.

See also Slesser M, Lewis C. Biological Energy Resources, E.and F N Spon Ltd, London, 1979.

33 Moreira J R, Goldemberg J. Alcohols: Its use, energy and economics- A Brazilian Outlook; Resource Management and Optimizatin 1 (3) 1983, pp. 231-279.

Borzani W. O Estado de São Paulo 21 May 1984; Rothman et al op.cit. pp.115-124.

34 See e.g. Rothman et. al. op.cit. pp.135-138.

For a view of the pullution problems in Brazil see Joyce C., The Price of Progress, New Scientist, 107 (1466) 25 July 1984, pp. 46-48.

35 O T A (1980) op. cit. p. II-211, table 64.

36 Branco G M. Toledo M P. Brazilian Evaluation of Alcohol on Automotive use and its air pollution concerns, IV Internat. Symp. Alcohol Fuels, op. cit. pp. 725-732.

Feracini V L, Fonseca M C P, Aldeidos en Exaustão de Motores a Etanol, Atualidades CNP, 15 (83) July/August 1983, pp. 27-32.

37 Alencar G. Quase pronto plano para reducir gases de carros, O Estado de São Paulo 15 September 1984, p 40.

38 Yeganiantz L. et al. The Envirionmental Impact of the Brazilian Bio-Energy Programme, V Intern . Symp. Alcohol Fuels, op. cit. Quoted in Margulis S, Environmental Impacts of the PNA, Paper presented at the University College London, op. cit.

39 For example in 1981 the pollution charge in the "Grande São Paulo" was 5700 ton of CO; 700 ton of HC; 600 ton of NOx; 320 ton of Sulphur oxides. O Estado de São Paulo 15 September 1984, p. 40.

40 Brown L. Food vs. Fuel: New Competition with the World's Cropland, Worldwatch Institute, Washington D C, Paper 35, 1980 Hudson W L, Biomass Energy and Food-Conflicts?, in Food and Energy Resources (Ed. D. Pimentel and C W Hall), Academic Press, Inc., 1984, Chap. 9, pp. 206-236.

41 Hall D O. Biomass: Fuel versus Food, A World Problem?, in Economics of Ecosystem Management, (Ed. M S Margaris) Publish. W Junk, Netherland, 1984, Chap. 2.4.; Hall D O. (1985) op. cit. p 29 ff.

42 Hall D O (1984) op. cit.

43 Quoted by Pearce F. In Defence of the Population Growth, New Scientist, 103 (1416) 9 August 1984, pp.12-16. Buringh P. estimates that the earth could produce 30 times the grain production of 1975. See Buringh P. van Heemst H D An estimation of World Food Production Based on Labour-oriented Agriculture, Centre for World Food Market Research, Wageningen, 1977, Netherlands.

44 Hall D O. (1985) op. cit. p. 48. This refers to FAO study "Potential Population Supporting Capacities of Lands in the Developing Worlds, FAO, Rome, 1984.

45 Pearce op. cit

The population growth philosophy is sopported by both Right and Left of politics. The Reagan Administration appears to have adopted this policy judging by its statement to the UN Population Conference in Mexico in 1984. The main Exponent is the Righ-wing Heritage Foundation.Julian Simon and Herman Kahn's book "The Resourceful Earth"(1984) forms an important new thinking in this area. Their themes are that there is no shortage of natural resources and that in a free market, population growth will generate rather than impede economic growth. The same echo was heared in Bucharest ten years ago, by Marxists. Only they argument that it is the enequalities of Simon's free market based capitalism that creates poverty and famine. There is enough food to go around " if the poor could efford to buy it".

46 R. Preto has 1.2 m/ha. of "cerrado" (30%); 1.1 m/ha. pasture land (29%); 0.67 m/ha. agricultural land (17%); 0.6 m/ha. of sugarcane. R. Preto produces 6% of Brazil's grain production; 22% of sugarcane; 35% of dairy products. See Lamartin Navarro Junior, Possibilidades de Producao e Aproveitamento do Alcool, STAB 2 (4) March/April 1984, pp. 5-9.

47 Matsunaga M, Instituto de Economia Agricola, Secretaria Agricultura,SP.Personal Communication, 13 August 1984. See also Rebolho Rego J M, O ProAlcool em São Paulo, Folha de São Paulo, 1 June 1984, p. 11.

48 Bautista Martin N Et. al. Analise do PNA e mas Implicações para o Setor Agrícola, Secretaria Agricultura SP.See also O PNA e seus Impactos na Agricultura Paulista. Ibid .

49 Borges J M (1984) op. cit.

50 See e.g. the III SINAC-Simposio Nacional de Consorciação de

Culturas com Cana-de-açúcar, Saccharum 7 (32) June 1984, pp.29-41. See also Folha de São Paulo 26 May 1984.

51 Another important characteristic to notice on the table is the decline of employment levels, aprticulary in the Northeast, as more efficient production methods are introduced.

As for the total employment impact, to produce 10.7×10^9 litres of alcohol would create, according to Coalbra, 511 000 to 598 000 men/year jobs equivalent. This is based on the assumption that 33% of alcohol production in 1985 would be produced in the Northeast (3.5×10^9 litres), and 67% in the Centre-South (7.2×10^9 litres). This means some 830 000 persons (275 000 permanently and 555 000 temporarily) annually. This represents 3.7% of the total agricultural employment in Brazil and over 25% of the new jobs in the whole agricultural sector. The greatest employment impact would be felt in the Northeast. See Coalbra-3, op. cit.pp.73-75.

52 Pereira A. Employment Implications of Ethanol Production in Brazil, International Labour Review 122 (1) January/February 1983, pp. 111-127.Figures given on table 8.7 also exclude net employment creation.

53 CENAL Relatorio Anual, CENAL 1985, p. 40.

54 Coalbra-3 op. cit. p.145 ff. and table 3.1

The total investment estimated by Coalbra to produce 10.7×10^9 litres of alcohol from sugarcane is $11.2 billion; and $12.7 billion in the case of wood-ethanol.

55 Coalbra-3 op. cit . pp. 87, 97.

For example if such expansion would have taken place in the

State of Maranhão which has a very traditional agriculture, employment could have been reduced by as much as 75%, according to Saint. See Saint W, Agricultura Energetica:opções socias no PNA do Brasil, Reforma Agraria, 1, Campinas, S.P.. Ass. Brasileira de Reforma Agraria.(undated)

56 Borges J M. (1984) IIICBE op. cit.. The most labour intensive crop is coffee which requires 33.2 men/ha./year. Coffee plantations have been destroyed in the past ten years because the fall on demand and raising production costs.

57 Geller op. cit.

58 Coalbra-3 op. cit. p. 147. Sabino Ometto J G. A Demanda Energética e a Produção de Alcool no Brasil, STAB 3 (6) July/August 1985, pp. 16-22.

59 Se e.g. Jose Marques M. Oferta e Demanda de Alcool- O Equilibrio Necessario, Atualidades do CNP 15 (82) May/June 1983, pp. 6-11.

60 Penna C. Interview with O Estado de São Paulo, 2 May 1984, p.41

61 See e.g. Wright op. cit pp. 221 ff.

62 Anon. Amaral Gurgel: Critica o ProAlcool mas não justifica, Vale Rural (2) July 1984. See also O Estado de São Paulo 20 May 1984.

CAPTER 9 NOTES AND REFERENCES

1 Drohan M. Energy Futures for oil-importing countries, Energy Policy 13 (3) June 1985, pp. 215-229.

2 See UNIDO: Development in Developing Countries in the 1980s, Doc. ID/WG.391/5, 29 March 1983.

3 Trindade S.C. Implementation of Alcohol Fuels: An International Perspective, Proceed. VI International Symp. of Alcohol Fuels, op. cit. pp.406-411.

4 Mendoça de Barros T R. Guarnieri L C. Energia Alternativa e o Futuro, Conjuntura 37 (8) August 1983, pp.84-91.

5 See UNIDO: Some Trends in World Industrial Development, Doc. ID/WG.391/8, 30 March 1983.

6 See UNIDO: Industrial Development Strategies and Policies for Developing Countries, Doc. ID/WG.392/7, 29 March 1983, p.4

7 Angelov I. Strategies and Policies for Industrialization in Developing Countries, in UNIDO: Industrial Development Strategies and Policies for Developing Countries, Doc. IS.431/Add.1, 29 December 1983, pp.11-41.

8 See UNCTAD:Technological Transformation of the Third World, Issues for Action in the 1980s, UNCTAD/TT/9, January 1978.

9 However the World Bank still regards the productivity of the distilleries rather poor, and because of the present world oil situation, the Bank seems reluctant to finance new projects. See Copersucar Especial Bulletim, June 1985.

10 Sussuna I. A Universidade pesquisa: O mito e a necessidade, R B T 6 (3) May/June 1985, pp. 5-14.

11 See Politzer K. Geração autónoma de tecnologias pelas empresas -Fatores condicionantes, R B T 16 (3) May/June 1985, pp.26-31.

12 Nunes J. As forças inibidoras de P & D na industria brasileira, R B T 16 (2) March/April 1985, pp.40-47.

13 Such role is very much a reality today.Excluding the financial sector, eight of the 10 largest companies in Brazil in 1984 (measured in total sales) were foreign owned. And among the top 50, half were subsidiaries of the MNCs. See Whitley A. Financial Times 19 August 1985, p.8

14 Wilkinson J. A Agricultura e as realidades da agroindustria, R B T 16 (3) May/June 1985, pp.43-47.

15 Whitley A. Financial Times 20 August 1985, p. 4.

16 See e.g. Martins Carvalho H. Tecnologias socialmente apropriadas: Muito alem da semántica, R B T 16 (3) May/June 1985, pp. 32-48.

17 Take for example Petrobras, which hardly pays any tax on most of its equipment and many other items.

18 Fluck R. Issues in Energy Farming, Energy in Agriculture, 3 (4) 1984, pp. 377-382.

19 Few changes are expected from the Sarney's Adminstration with regard to the ProAlcool, according to Mont'Alegre O. Director of the IAA in London. Personal Communication 1 August 1985. If anything it is possible that the programme may increase its influence due to the new emphasis on the private sector and against the state sector.The ProAlcool is privately controlled.

APPENDIX 1

LIST OF THE MAIN RESEARCH INSTITUTIONS, COMPANIES ETC. VISITED IN BRAZIL.

ABDIB,
Rua General Jardim, 645,
SP-SP.

ABIQUIM,
Rua Santo Antonio 184,
SP-SP.

ANFAVEA,
Avenida Indianópolis, 496,
SP-SP.

AVIOVE-Associação Brasileira das Industrias de Óleos Vegetáis,
Avenida Paulista, 460,
SP-SP.

Banco do Brasil S.A.
Divição de Análise de Projetos,
Setor Bancario,
Brasilia, D.F.

BIOBRAS-Bioquímica do Brasil S.A,
Praça das Chargas, 49.
Belo Horizonte,
M.G.

Centro de Pesquisa da Petrobras,
Ilha do Governador,
UFRJ,
RJ-RJ.

Centro Tecnológico Aeroespacial,
Instituto de Pesquisa e Desenvolvimento,Divição Mecánica,
Sào José dos Campos,
SP.

CATI-Centro de Assessoramento de Tecnología Integral,
Avenida do Brasil,
Campinas,
SP.

CBT-Companhia Brasileira de Tratores,
São Carlos,
SP.

CEBTA-Centro de Biotecnologia Agrícola-ESALQ.,
Piracicaba,
SP.

CENA-Centro Nuclear na Agricultura,
Piracicaba,
SP.

CENAL,
Esplanada dos Ministerios,
Brasilia, D.F.

Conselho Nacional do Petróleo,
Brasilia, D.F.

Conselho Nacional de Desenvolvimento Científico e Tecnológico,
Avenida W3/Norte 507,
Brasilia, D.F.

CESP,
Avenida Paulista 2674,
SP-SP.

COALBRA-Coque e Alcool da Madeira S A.,
Avenida São Gabriel 555,
SP-SP.

CODISTIL-Constructora de Destilarias Dedini S A.,
Rod. Rio Claro,
Piracicaba,
SP.

CEE-Conselho Estadual de Energia,
Rua Estados Unidos 346,
SP-SP.

CONGER S A.-Equipamentos e Processos,
Rua Fernando López 1767,
Piracicaba,
SP.

Cosultoria e Planejamento,
(Romeu Boto Dantas)
Parnamirim,
Recife,
PE.

CPFL-Companhia Paulista de Força e Luz,
Rod. Campinas,
Campinas,
SP.

CTC-Centro de Tecnologia Copersucar,
Piracicaba,
SP.

Copersucar,
Rua Boa Vista 280,
SP-SP.

COPPE-Coordenação dos Programas de Pos-Graduação,
(Centro de Tecnologia)
UFRJ,

DEDINI S A.- Metalúrgica,
Avenida Limeira 222,
Piracicaba,
SP.

EMBRABIO-Empresa Brasileira de Biotecnologia,
Rua Marques de Itú 58,
SP-SP.

EMBRAPA,
Edificio Venancio 2000,
Brasilia, D.F.

ESALQ,
Departamento de Tecnología Rural,
Piracicaba,
SP.

Escola de Engenharia de São Carlos,
Avenida Carlos Botelho 1465,
SP.

FAZANARO-Fazanaro Industria e Comercio Ltda,
Rua Bom Jesús 1663,
Piracicaba,
SP.

FINEP,
Avenida Rio Branco 124,
RJ-RJ.

Federação das Industrias do Estado de São Paulo,
Avenida Paulista 1313,
SP-SP.

Fermentec S/C Ltda.,
Rua J. Oliveira Algodal 399,
Piracicaba,
SP.

FIAT,
Betim,
Belo Horizonte,
MG.

FIPE-Fundação Instituto de Pesquisas Económicas,

Cidade Universitaria,
SP-SP.

FORD Brasil S A.,
São Bernardo do Campo,
SP.

FTI-Fundação Tecnología Industrial-MG.
Avenida Contorno 55489,
Belo Horizonte,
MG

FTI-Fundação Tecnologia Industrial,
Avenida Messias Ribeiro 625,
Lorena,
SP.

Industrias Químicas Taubaté S/A,
Taubaté,
SP.

Instituto do Açúcar e Álcool,
Superintendencia Regional,
Rua Formosa 367,
SP-SP.

IAA/Planalsucar,
Avenida Rio Claro,
Piracicaba,
SP.

IAA/Planalsucar,
Estação Experimental,
Araras,
SP.

Instituto Agronómico de Campinas,
Avenida Barão de Itapura 1481,
Campinas,
SP.

Instituto de Administração,
(Programa de Estudos do Futuro)
Cidade Universitaria,
SP-SP.

Instituto Brasileiro do Petróleo,
Avenida Rio Branco 156,
RJ-RJ.

Instituto de Estudos e Pesquisas Económicas,
Universidade Federal Rio Grande do Sul,
Porto Alegre,
RS.

Instituto de Economía Agrícola,
Avenida Miguel Estefano 3900,
SP-SP.

Instituto de Engenharia,
Palacio Mauá,
Viaduto Dona Paulina 80,
SP-SP.

Instituto Mauá de Tecnología,
Estrada das Lágrimas 2035,
São Caetano do Sul,
SP.

INPI-Instituto Nacional da Propiedade Industrial,
Praça de Mauâ 7,
RJ-RJ.

Instituto Nacional de Tecnología,
Avenida Venezuela 82,
RJ-RJ.

IPT-Instituto de Pesquisas Tecnológicas do Estado de São Paulo,
Cidade Universitaria,
SP-SP.

ITAL-Instituto de Tecnología de Alimentos,
Avenida Brasil 2880,
Campinas,
SP.

Instituto Zootécnico,
ESALQ,
Piracicaba,
SP.

Ministerio da Agricultura,
Esplanada dos Ministerios,
Brasilia, D.F.

Ministerio da Industria e do Comercio,
Esplanada dos Ministerios,
Brasilia, D.F.

Ministerio das Minas e Energia,
Esplanada dos Ministerios,
Brasilia, D.F.

MAUSA S A-Equipamentos Industriais,
Rua Santa Cruz 1482,
Piracicaba,
SP.

Mercedes-Benz do Brasil S A.
São Bernardo do Campo,
SP.

OXITENO,
Avenida Brig. Luis Antonio 1343,
SP-SP.

PETROQUISA-Petrobras Química S A.,
Avenida Rio Branco 80,
RJ-RJ.

PROMON Engenharia S A.,
Avenida Nove de Julho 4939,
SP-SP.

Rhodia,
Avenida Maria Coelho Aguiar 215,
SP-SP.

Secretaria de Economía e Planejamento,
Palacio dos Bandeirantes,
Avenida Morumbí s/no.
SP-SP.

Secretaria de Tecnologia Industrial ,
SAS, Quadra 2,
Brasilia, D.F.

SEPLAN,
Esplanada dos Ministerios,
Brasilia, D.F.

SOPRAL-Sociedade de Produtores de Açúcar e Alcool,
Rua Augusta 1600,
SP-SP.

STAB-Sociedade dos Tècnicos Açucareros e Alcooleiros do Brasil,
Piracicaba,
SP.

SUCRAL-Assessoria e Projetos para Açúcar e Alcool, S/C.
Praca J. Bonifacio 799,
Piracicaba,
SP.

Usina Santa Elisa S A.,
Sertaozinho,
SP.

Uiversidade Federal de Ceará,
Fortaleza,
CE.

Volkswagen do Brasil,
Departamento de Novas Tecnologias,
Rua Vemac 1036,
São Bernardo de Campo,
SP.

Zanini S A-Equipamentos Pesados,
Via Armando de Salles,
Sertaozinho,
SP.