An Assessment of Sustainable Bioenergy in Brazil: National Overview and Case Study for the Northeast

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(The technical appendices for this working paper are available as a separate document.)

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WOOD FOR ENERGY IN BRAZIL

1. INTRODUCTION

The purpose of this study is to show the possibilities of using biomass as an energy source in Brazil and opportunities that could be opened by its use on an extensive basis. It also has the objective of giving a good idea of Brazil's unique infrastructural capabilities for dealing with biomass and of Brazil's natural features, both of which enhance the country's potential to use biomass as a multipurpose prime energy source to produce electricity, liquid fuels or gas. Finally, we will undertake a detailed case study of the utilization of two major biomass resources, wood from short rotation planted forests and sugar cane residues, for electricity production in Northeast Brazil.

To develop a good understanding of the role that biomass has played historically in Brazil and broad future possibilities for its use as an energy source, it is important to begin with some basic information about the country, such as its geographical situation and size, population, economic and other natural features. These will be or already are part of the whole biomass utilization context.

It is also important to have a clear idea of how the use of biomass is progressing, mainly in the industrialized countries, and what is seen as its most likely future role, not only as an energy source, but also as a means to decrease the presence of CO_2 in the atmosphere. In other words, it is important to have in mind that the growing consciousness about the world environment and its finite resources, from an ecological standpoint, can be a significant factor in influencing the use of biomass on a national, structured and entrepreneurial way. This introductory chapter will bring up this kind of information as background for the following chapters, where the most important aspects related to the use of biomass and to the aims of this study will be detailed.

The following chapters will bring forth some information about Brazil's experience with biomass use, the country's natural resources and the technical, economic and social aspects related to the most promising biomass resources. Finally, a case study where biomass is used as a prime energy source to generate electricity in the Northeast region of Brazil will be made. Based on this study conclusions and suggestions for future biomass development policies are discussed in the concluding chapter.

1.1 BRAZIL - BASIC GEOGRAPHIC AND POPULATION DATA

Brazil, with an area of 8,511,965 km², comprises about 49% of South America and is situated between the latitudes 5°16'20" N and 33°45'10"S and longitudes 34°47'30" W and 13°59'32" W. Its eastern border is the Atlantic ocean, having a shoreline of about 7,408 km (Fig. 1-1).

Fig 1.1

The country is divided into five main regions which are shown on Fig. 1-2 and Table 1-1. From Table 1-1, one can see that 40% of the country is represented by the North region and that North and Center-West regions comprise approximately 65% of the whole country.

Brazil is one of the largest countries of the world - bigger than the continental United States and smaller than only Russia, China, Canada and the total U.S.

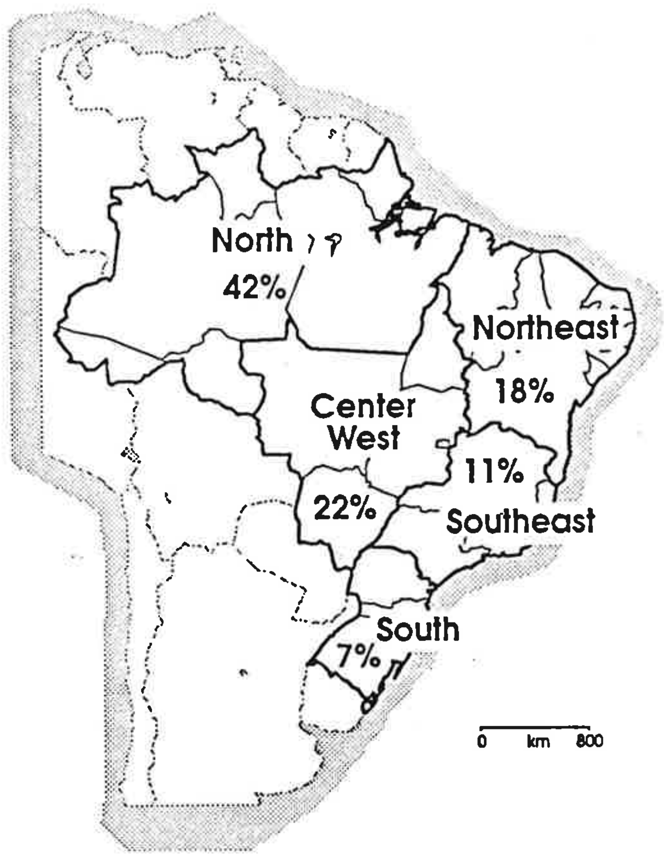


Fig 1.2: Area distribution

TABLE 1-1
REGIONS OF BRAZIL

Region	States	Area km^2	% Brazil
North	Amazonas Acre Rondonia Roraima Para Amapa	3581180	42.07
Northeast	Maranhao Piaui Ceara Rio Grande do Norte Paraiba Pernambuco Alagoas Sergipe Bahia	1548672	18.2
Southeast	Minas Gerais Espirito Santo Rio de Janiero Sao Paulo	924935	10.86
Sul	Parana Santa Catarina Rio Grande de Sul	577723	6.79
Center West	Mato Grosso Mato Grosso de Sul Goias Tocantins	1879455	22.08

In terms of population, the best estimates show that the country has, at present, about 150.6 million people with the distribution shown in Table 1-2.

TABLE 1-2
BRAZIL POPULATION DISTRIBUTION AND GROWTH RATES

Region	1,000 Inhab 1990	% Brazil	Actual Growth Rates %/yr. 1987-1988	Average Growth Rates 1980-2000(%/yr)	people/km²
North	8893	5.9	2.93	3.79	2.48
Northeast	42822	28.5	1.81	1.85	27.65
Southeast	65559	43.6	2.00	2.13	70.88
South	22762	15.1	1.85	1.62	39.40
Center West	10332	6.9	2.51	2.87	5.50
Brazil	150638	100	2.01	2.108	17.7

Fig. 1-3 gives a good idea of the geographical distribution of the country's population.

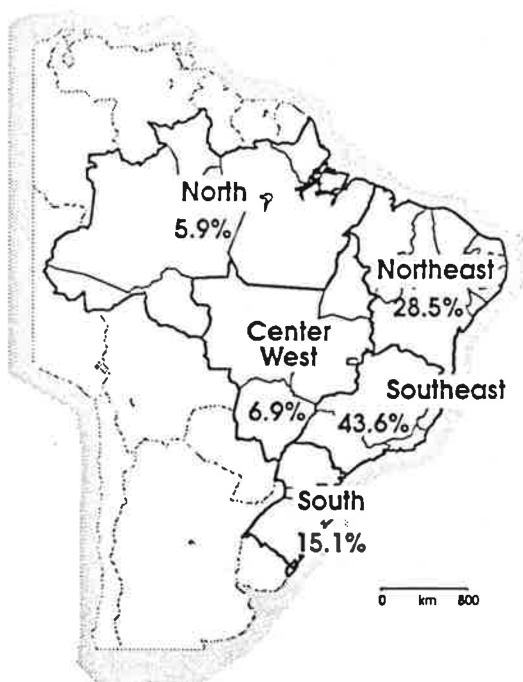


Fig 1.3: Population distribution 1990

respectively. Almost 60% of the population is in the South and South East which comprise 18% of the country's area. The North and Center West with 65% of the area have only 13% of the population. If we look at the North, Center West and Northeast, we will see 82% of the country's area with 41% of its population. All of these figures indicate a very uneven population distribution.

Another fact that shows up is that the general trend is a decrease of the growth rates and also that, up to the year 2000, no major modifications will occur on the actual situation. (See Table 1-3)

TABLE 1-3
BRAZIL POPULATION DISTRIBUTION
FORECAST YEAR 2000

Region	1000 Inhabitants	% Brazil
North	11490	6.4
Northeast	50182	28.0
Southeast	78151	43.5
South	26792	14.9
Center West	12871	7.2
Brazil	179486	100.0

1.2 BRAZIL - SOME ECONOMIC AND SOCIAL DATA

A good idea of the economic and social situation of Brazil may be obtained through the observation of some well established parameters such as GNP, GNP per capita, inflation, unemployment and illiteracy rates. It is also interesting to have an idea of the time evolution and geographic distribution of these parameters.

In Table 1-4 we can find the country's Gross National Product (GNP) as seen by various sources. It is worth noting the difference in figures even for the same year, as is the case for the years of 1987 and 1988. Any way the country presents a GNP in the year 1988 around US$ 320 billion with a per capita GNP around US$ 2100.

TABLE 1-4
BRAZIL GNP BY INFORMATION SOURCE - 1970/1988
FIGURES IN BILLION 1988 US$

Year	Brazil Yearly Statistic-89 IBGE	World Bank Atlas-89	World Bank Tables-88/89	World Bank W.Devel. Report 90	World Resources 1990/1991
70	117089		117683		
75	189358		190982		
80	267950		264107		
85	283392		281870		
87	315879	296189	320291		295374
88	315009	328860		311904	

OBS: All figures adjusted to 1988 US dollars using the Implicit Price deflectors for GNP of the Economic Indicators Sept. 1990 U.S. Government.

Cruzados converted to U.S. Dollars using the Cruzado Dollar exchange rate of the last day of Dec/80.

Table 1-5 gives more detailed information about the GNP per capita and once again there are some differences in the figures, particularly with reference to the years of 1980 and 1987, where the discrepancies are around 33%. In general, the GNP per capita has had a steady growth during the 70s, where it increased from about US$ 1200 to more than US$ 2200. Between 1980 and 1988 it fluctuated in the range of US$ 2000 and US$ 2200.

TABLE 1-5
GNP PER CAPITA 1970-1988
BY INFORMATION SOURCE
(Figures in 1988 USD)

Year	BR Yearly Statistic-89 IBGE	World Bank World Tables 88/89	World Bank Atlas 89
70	1222	1571	1235
75	1752	2236	2139
80	2209	2703	2944
85	2091	2534	1870
87	2234	2802	2087/2097
88	2181		2280

OBS: All figures adjusted to 1988 US dollars using the Implicit Price deflators for GNP of the economic indicators Sept. 90, U.S. Government.

Cruzados converted to U.S. Dollars using the Cruzado Dollar exchange rate of the last day of Dec/80.

Tables 1-6 and 1-7 give the growth rates GNP and GNP per capita growth for various periods of time. Two facts are very clear. The first is that during the period 70-79, both the GNP and the per capita GNP have experienced high growth rates which means that the country and the personal income have increased during this time. On the other hand, in the period 80-88, the GNP has had smaller growth rates, around 3.0%, and the per capita GNP has grown even less, increasing around 1.0% a year, with a decrease in the period 86/88. This means that although the country's economy has experienced a moderate development in the last 9 years the personal income practically hasn't improved.

TABLE 1-6
BRAZIL GNP GROWTH RATES FOR VARIOUS PERIODS (%)

Period	Br. yearly Statistics-89 IBGE	World Bank Atlas-89	World Bank World Devel Report-90	World Resources 90/91
65-88			3.6	
67-77				10.0
70-88	5.66			
77-87	3.86			3.2
71-79	8.55			
80-88	2.85	3.4		

TABLE 1-7
BRAZIL GNP PER CAPITA GROWTH RATES (%)

Period	Br. yearly Statistics 89 IBGE	World Bank Atlas 89	Brasil Central Bank 89
71-79	6.02		
80-88	0.67	1.2	
82-88			0.84
86-88		(-0.3)	

Other valuable information is the regional GNP and per capita GNP distribution inside the country (Fig. 1-4).

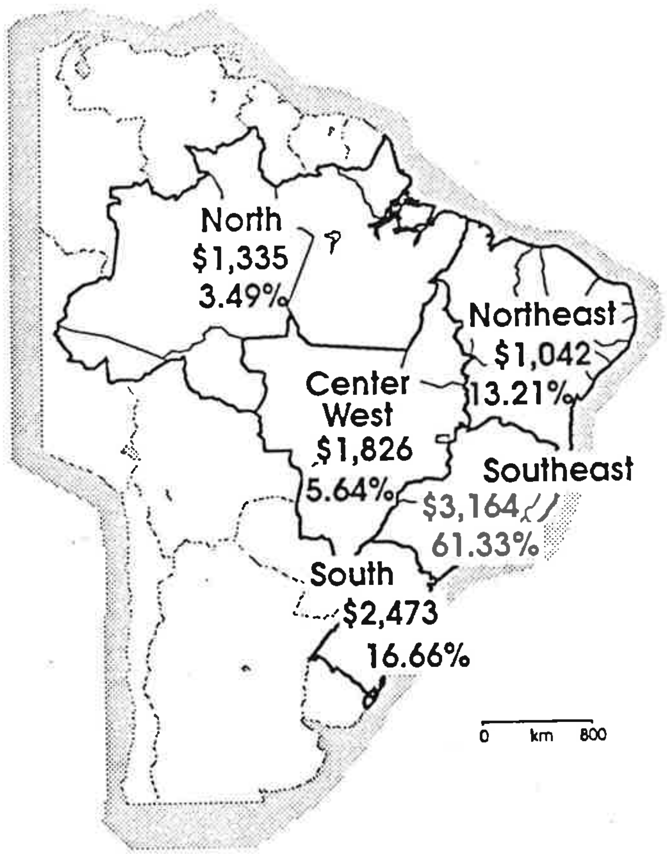


Fig 1.4: GNP per capita
BR-$ 2,250 (1988)

Finally, Table 1-8, shows a comparison of the gross and per capita GNP between Brazil and other countries. In this table are found countries with the same size economies, countries in which economies are smaller, and the countries with the largest economies in the world. These figures show very clearly that although Brazil's economy as a whole is among the ten largest, the personal income still remains very far from the situation achieved by the industrialized countries.

TABLE 1-8
GNP AND PER CAPITA GNP COMPARISON
FIGURES IN 1988 USD

Country	GNP Gross (billion USD)	Per Capita GNP (USD)
Brazil	328.9	2280
Canada	437.5	16760
Spain	301.8	7740
Australia	204.5	12390
China	356.5	330
Portugal	37.3	3670
Yugoslavia	63.1	2680
Venezuela	83.0	2640
Germany	1131.3	18530
Japan	2576.5	21040
United States	4863.7	19780
United Kingdom	730.0	12800
Italy	765.3	13320

Source: World Bank Atlas - 89

Two other important social economic parameters are the annual inflation and unemployment rates. With regard to these rates, Brazil has a very peculiar situation because even with high inflation unemployment has been low, probably as a result of the indexation system adopted by the country. This situation can be better understood through the figures in Tables 1-9 and 1-10 where it is seen that the average inflation for the last 9 years has been 188% per year and also that it sharply increased in the years of 1987 through 1989. Unemployment in the latter 1980's has been in the range of 3.7% to 3.9%. It is important to note that when we consider the unemployment by region, the NE appears with an average rate just below 5%, which is about 31% higher than the country average.

TABLE 1-9
BRAZIL INFLATION RATES

Period/Year	Average Annual Inflation (%)
65-80	31.5
80-88	188.7
87	366.0
88	934.0
89	1765.0

Sources: World Bank; World Development Report 90; IBGE.

TABLE 1-10
BRAZIL UNEMPLOYMENT RATES

	1986	1987	1988	
Brazil	3.59	3.73	3,85	
Recife	4.39	5.18	5.06	NE
Salvador	4.54	4.08	4,63	
Rio de Janeiro	3.49	3.24	3.09	SE
Sao Paulo	3.34	3.76	4.02	
Belo Horizonte	3.72	3.92	4,02	
Porto Alegre	3.87	3,92	3,63	S

Source: IBGE yearly statistics of Brazil 89

A final aspect of Brazil's socioeconomic situation is illiteracy rates. Figure 1-5 shows how they are distributed by region within the country. Table 1-11 contains the figures from various sources for 1985.

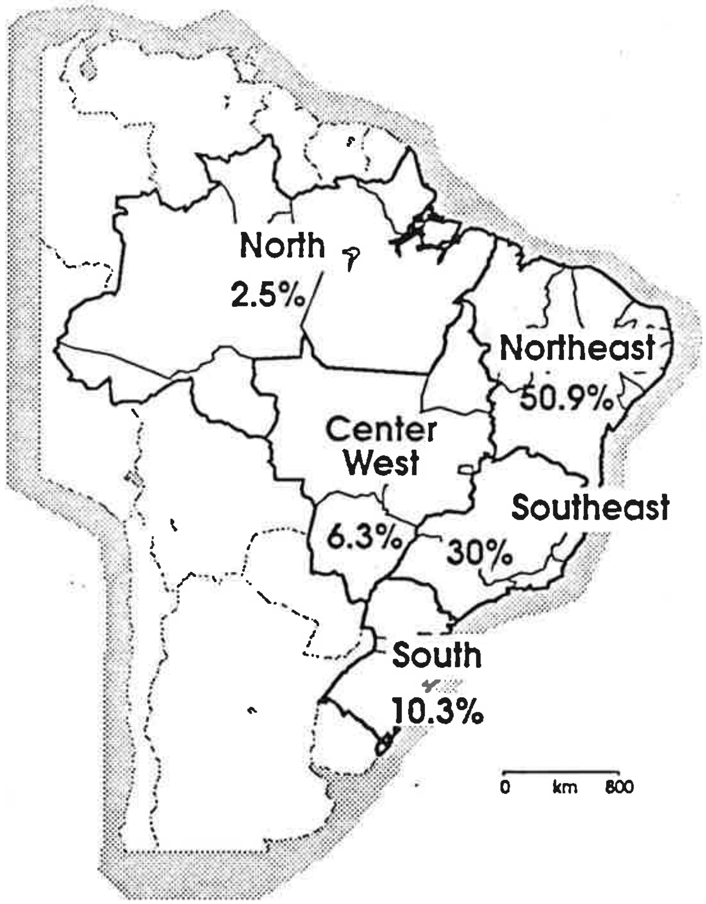


Fig 1.5: Illiteracy distribution

Total illiteracy = 0.13 * 150,638,000 = 19,582,940 people

 from p.16

TABLE 1-11

BRAZIL ILLITERACY RATES AS % OF THE TOTAL POPULATION
AS OF 1985

Yearly Statistics of Brazil-89 IBGE	26.5
World Bank Atlas 89	22.0
World Bank World Devel. Report 90	23.0
World Resources 90/91	22.5

The fact that calls for our attention is that more than half of the illiterate people live in the Northeast. They account for approximately 13% of the country's population and almost 46% of the Northeast's population. On the other hand, although the illiteracy rates are high, the situation has been improving during the past few years. In 1970, the illiterates accounted for 34% of the total population, and in 1986, this number has decreased to 26.5% according to IBGE.

1.3 BRAZIL - ENERGY FEATURES.

The main sources of energy used in the country are water, petroleum, (indigenous or imported), natural gas, some coal, and biomass. Biomass is understood here as wood fuel, charcoal, and sugarcane. Sugarcane is used to produced alcohol as a substitute for gasoline. The fibrous residue of alcohol or sugar production (bagasse) is also used as an energy source by these industries.

A good picture of Brazil's energy situation can be drawn from some basic information about each of the main energy sources actually in use. These aspects are potential resources, installed capacity, production and consumption.

1.3.1 WATER RESOURCES

Brazil has 9 major hydro basins (as shown in Figure 1-6) from which most of its electricity is derived. These basins have an energy potential of 106,570 MWy/y as seen in Table 1-12.

BACIAS HIDROGRÁFICAS

Fig. 1.6
Hydrographic Basin

TABLE 1-12
BRAZIL HYDRO ENERGY POTENTIAL

Basin	MWy/y
Amazonic	36163
Left Bank Tributaries	7770
Right Bank Tributaries	28393
Xingu River	10454
Tapajor River	9610
Madeira River	8170
Others	159
Tocantins	12660
North	485
Northeast	442
Sao Francisco	9150
East	6656
Parana	29030
Southeast	4708
Uruguai	7276
Total	106570

Source: Eletrobras/IBGE

The power potential of each region of the country is shown in Fig. 1-7 and amounts to 213000 MW, of which 24% is being used or is under construction. Fig. 1-8 shows the installed capacity and the main production data as of 1987 (Eletrobras). Figure 1-9 shows a breakdown by region of the major power plants (hydro and thermal) in operation, under construction or in the planning phase.

THE BRAZILIAN HYDROELECTRIC POTENTIAL (kW)

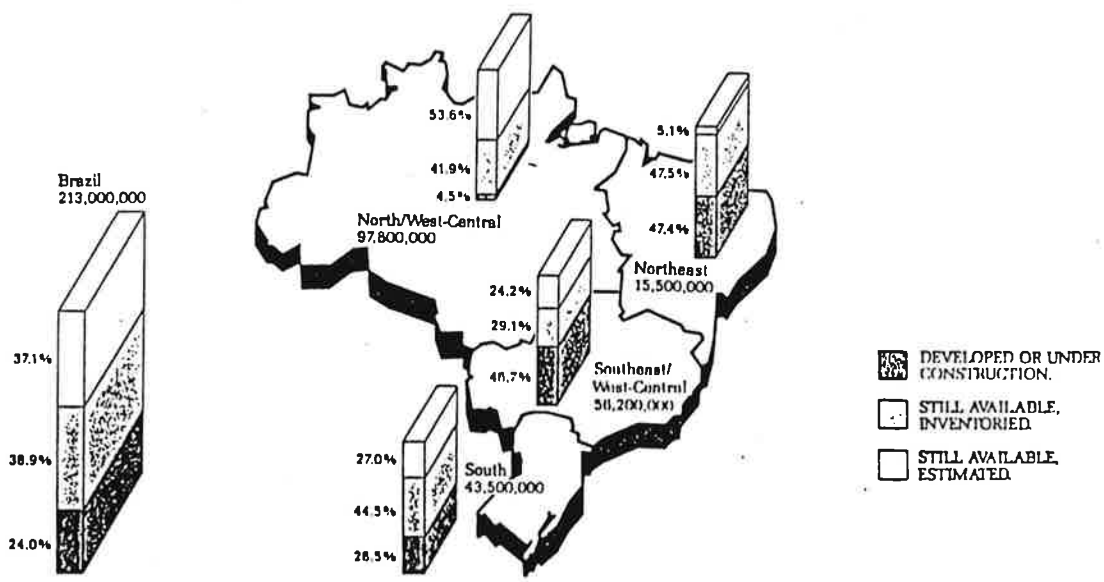


Fig. 1.7

Source: Electrobas

Fig. 1.8

Source: Eletrobras

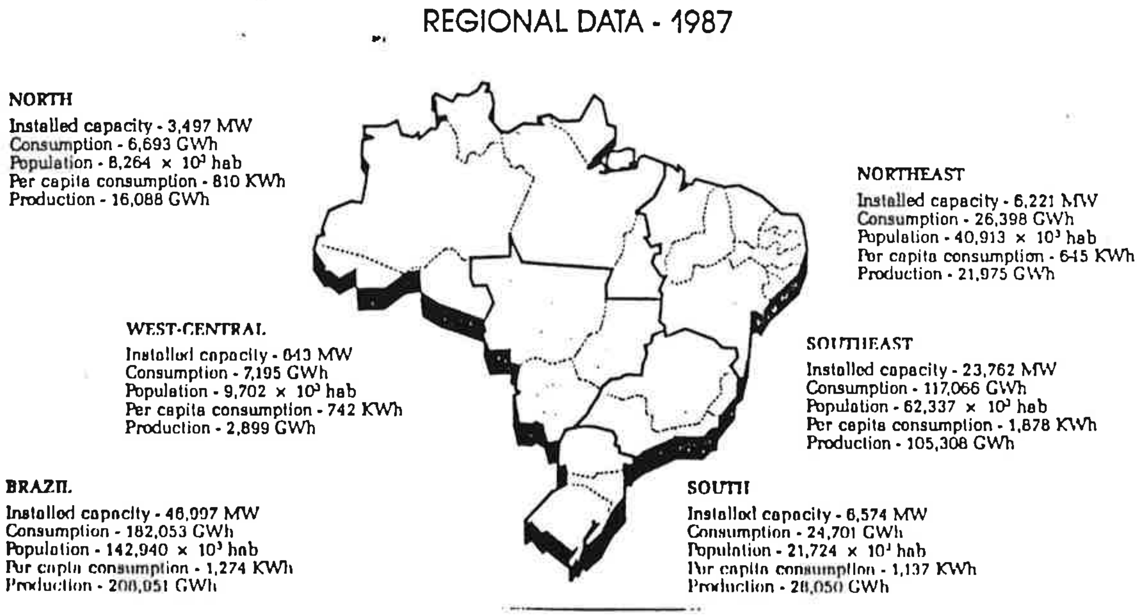


Fig. 1.9

Source: Eletrobras

Table 1-13 provides updated information about the installed capacity, production and consumption of electricity. From these data it becomes clear that whereas most of the generating capacity is in the North of the country, the major consumption occurs in the South and Southeast (more than 75%). This fact, in conjunction with the fact that most of the North Region's economic resources remain to be developed, poses the biggest challenge to be solved by the country's future electricity policy. It must provide the electric energy needs necessary to maintain the country's development without disrupting regional opportunities and, even more, using the opportunity to decrease the economic discrepancies among regions.

Another important fact is that the hydro resources existing in the Northeast are almost fully tapped. This factor can open many opportunities for development of new sources of energy, which will bring with them a whole new spectrum of progress. Until now, these issues have gone largely unexplored from the political, economic, technical and social standpoints.

TABLE 1-13
BRAZIL'S INSTALLED CAPACITY PRODUCTION AND CONSUMPTION OF ELECTRICITY INCLUDING ITAIPU
1988

	Instal. Capac. (MW)	Gross Production (GWh)	Consumption (GWh)
Brazil	53166	231951	202349
North	3685	19486	7662
Northeast	7291	24649	30421
Southeast	25838	122921	128480
South	7167	23886	27830
Centerwest	785	3924	7956
Itaipu	8400	37085	

1.3.2 PETROLEUM AND NATURAL GAS

Electric, petroleum, and natural gas resources are developed and managed by state owned companies, the last two primarily by Petrobras. The company is one of the most successful state enterprises. It is the country's largest company and is among the foremost in the world. It has made substantial improvements in developing the resources under its responsibility, especially considering the troubled environment under which it operates.

Brazil's reserves of petroleum and natural gas are not very extensive, but have been expanding reasonably with the new discoveries in the last years, mainly offshore. The major reserves are situated in the Northeast and Southeast regions as can be seen in Table 1-14 and Figure 1-10.

TABLE 1-14

BRAZIL NATURAL GAS RESERVES 1987 (10^6 m^3)

Region	On shore	Off shore	Total
North	7681.35	991.02	8672.37
Northeast	42293.67	12730.30	55023.97
Southeast	1816.24	39784.92	41601.16
Total	51791.26	53506.24	105297.50

Source: Petrobas 100%=105.3 * 10^9 m^3

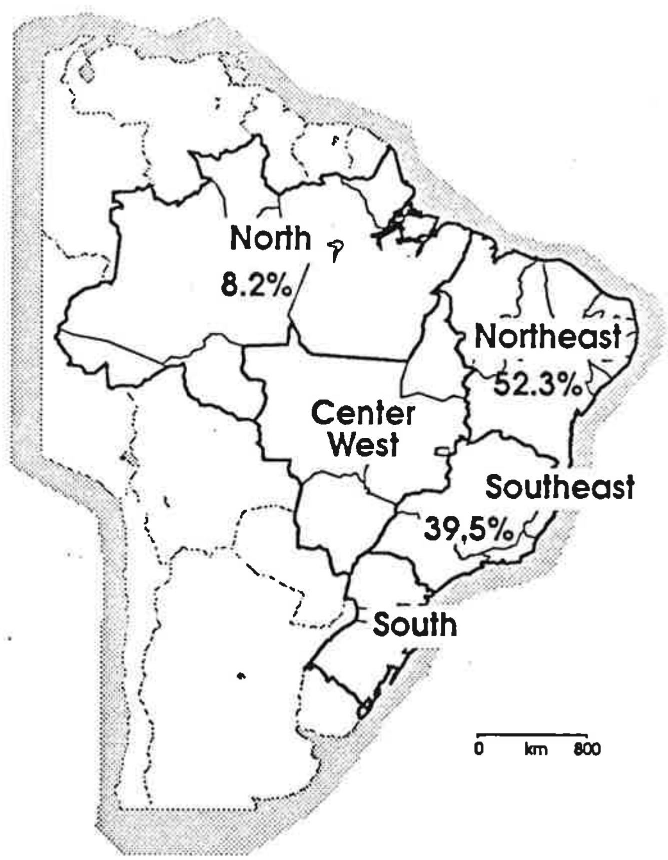


Fig 1.10: Natural gas reserves

Brazil's petroleum production in the year 1988 was 32.2 million m^3 as seen in Table 1-15, of which 12,4 came from the Northeast and 19.8 from the Southeast, accounting for more than 98% of the total production.

TABLE 1-15
BRAZIL'S PETROLEUM PRODUCTION AS OF 1988 (m^3)

	On Land	Offshore	Total
Brazil	10416283	21820974	32237257
North	13848		13848
AM	13848		13848
Northeast	9636523	2770234	12406757
MA	474		474
CE	230280	732850	963130
RN	2502653	1020175	35222828
AL	578922		578922
SE	2050653	749326	2799979
BA	4273541	267883	4541424
Southeast	765912	19050740	19816652
ES	765912	197540	963362
RJ		18853290	18853290

Source: IBGE-Petrobras

Table 1-16 shows the evolution of petroleum production since 1970. It has more than tripled in the last 20 years, although the last two years have shown a slight production decrease, reflecting the shortage of investment occurring in this period.

TABLE 1-16
BRAZIL - EVOLUTION OF PETROLEUM PRODUCTION

Year	Production	Average Annual Variation (%)
1970	9533944	
1975	9978880	0.9
1980	10562401	1.1
1985	31709403	24.6
1986	33200393	4.7
1987	32829016	(-1.1)
1988	32237257	(-1.8)

Source: IBGE-Petrobras

Table 1-17 shows the evolution of petroleum refined between 1977 and 1988. The percentage of indigenous oil in the total refinery mix has increased from about 17% to 50%. A slight decrease has been observed in the last years for the same reasons previously mentioned.

TABLE 1-17
EVOLUTION OF BRAZILIAN PETROLEUM REFINING
REFINED PETROLEUM (m^3)

Year	Total	%	Indigenous (5)	Imported (%)
1977	55722110		16.6	83.4
		13.3		
1980	63158482		16.2	83.8
		(-6.7)		
1983	58899519		31.0	69.0
		7.4		
1985	63265603		49.3	50.7
		5.9		
1986	67033937		49.4	50.6
		2.3		
1987	68581528		47.7	52.3
		0.5		
1988	68948056		46.2	53.8

Source: IBGE-Petrobras

Table 1-18 shows the consumption of petroleum products by region. The Southeast accounts for 53% of the total and the South and Southeast for more than 70% of the total. This reflects the large economic discrepancies existing in Brazilian socioeconomic system.

TABLE 1-18
BRAZIL'S CONSUMPTION OF PETROLEUM PRODUCTS AS OF 1988

	m^3	%
Brazil	56866780	100.0
North	3337868	5.9
Northeast	8535030	15.0
Southeast	30076327	52.9
South	9790657	17.2
Center West	5126898	9.0

A comparison between production of petroleum and consumption of its products, is shown in Table 1-19 and Fig. 1-11. The Northeast is the only net exporting region in the whole country. It is important to mention that this is not a new situation; although it is not clear whether the benefits gained have been in proportion to the accelerated exploitation of this non-renewable resource and how they are being used. These two issues are not well defined and it seems, not properly addressed by the energy policy makers.

TABLE 1-19
COMPARISON BETWEEN INDIGENOUS PRODUCTION OF PETROLEUM AND THE CONSUMPTION OF PETROLEUM PRODUCTS PER REGION (%)

	Indigenous Petroleum Production	Indigenous Petroleum Production Compared to the Consumption of Petroleum Products	Consumption of Petroleum Products
North	0.04	0.023	5.90
Northeast	38.50	22.0	15.00
Southeast	61.46	35.0	52.90
South	---	---	17.20
Center West	---	---	9.00

Source: IBGE-Petrobras-MME

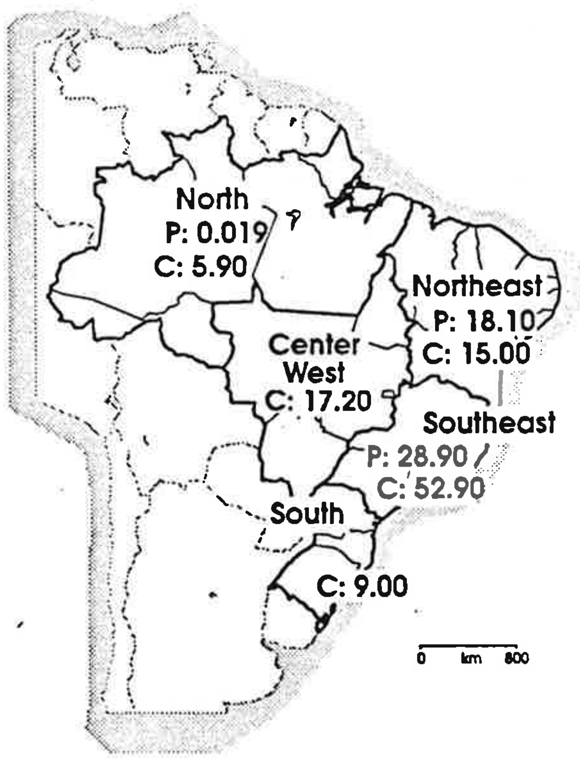


Fig 1.11: Petroleum production (P) and consumption (C) (%)

Questions such as, how long it will last, what a fair revenue would be for the exploitation and how the future should be addressed, are not answered nor have they ever been openly discussed, and if no action is taken, it may result in a new future burden to be bourne by the less economically developed region of the country.

For natural gas a different scene exists as most of the production and consumption actually occurs within the same region. Natural gas is a resource that may be considered underdeveloped or is in a transition period. Only in the last seven years or so has a utilization policy been established and more attention has been given to the use of natural gas. New fields are being discovered and more facilities developed. A steady increase in its use can be envisaged.

Table 1-20 shows the evolution of its production and consumption in the period between 1970 and 1988, with a total growth of more than 4.5 fold.

TABLE 1-20
BRAZIL - EVOLUTION OF NATURAL GAS PRODUCTION AND CONSUMPTION

Year	Production ($1000m^3$)	Annual Variation (%)
1970	1263608	
		28.6
1975	1624588	
		35.7
1980	2205269	
		148.0
1985	5468251	
		4.0
1986	5686381	
		1.7
1987	5785681	
		1.0
1988	5844106	

Fig. 1-12 and Table 1-21, give an idea of the 1988 use of natural gas by region. It is interesting that contrary to other energy sources, natural gas has been developed only in the Northeast and Southeast regions.

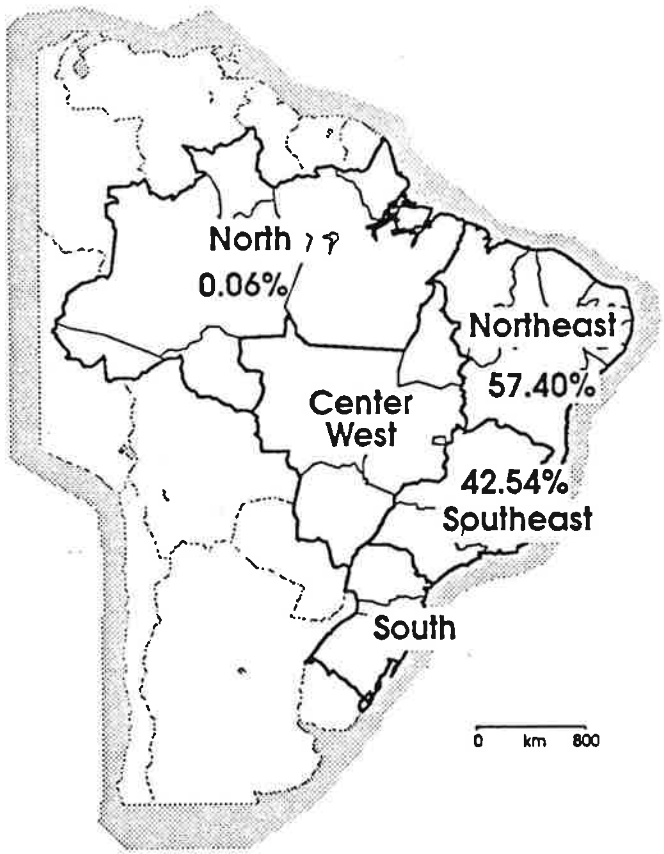


Fig 1.12: Natural gas production and consumption

TABLE 1-21
BRAZIL - PRODUCTION AND USE OF NATURAL GAS AS OF 1988
(1000 m^3)

	Onland	Offshore	Total
Brazil	2062049	3782057	5844106
North	3381		3381
AM	3381		3381
Northeast	1929839	1422177	3352016
MA	37		37
CE	1581	97078	98659
RN	107702	543021	650723
AL	416984		416984
SE	99185	738352	837537
BA	1304350	43726	1348076
Southeast	128829	2359880	2488709
ES	128829	29755	158584
RJ		2330125	2330125

Source: IBGE - Petrobras

1.3.3 SUGAR CANE, ALCOHOL AND BAGASSE

Brazil has been growing sugar cane for centuries. It is probably one of the oldest, or the oldest, agricultural outputs in the country's history. Until 1975 practically all attention was directed to growing sugarcane for sugar production. Only in the last 15 years, as a function of the seventies oil crisis, alcohol (ethanol) has emerged as a main product of the sugarcane industry. Recently a byproduct of sugar and alcohol production, the bagasse, is receiving greater attention as another source of energy.

This new approach has begun to modify the industry profile and, if it is pursued further, more profound modifications are likely to be seen, all of them aiming to improve not only the overall process energy efficiency, but also the industry's competitiveness. Under this new approach a sugar mill or distillery will be seen, not only as a producer of sugar or alcohol, but also of electricity or a biomass fuel based on the bagasse surplus. As background for subsequent analysis, a summary of basic information about Brazil sugar cane, alcohol and bagasse production and consumption is now presented.

As for natural gas, most of the energetic products of sugarcane processing are consumed in the areas where they are produced.

Table 1-22 shows the evolution of sugar cane and bagasse production between 1975 and 1988. The effect of the "Proalcohol" program on the production levels, which more than tripled in a ten year period (1975 to 1985), stabilizing at around 225 million tonnes per year in the last harvests, mainly as a consequence of low world oil prices.

TABLE 1-22
BRAZIL EVOLUTION OF SUGAR CANE AND BAGASSE PRODUCTION
(1000t)

Harvest	Sugarcane	Average Annual Growth (%)	Bagasse
75/76	68322.6		20496.8
		14.5	
79/80	117324.4		35197.3
		11.5	
84/85	202618.4		60785.5
		10.4	
85/86	223673.7		67102.1
		1.9	
86/87	227875.8		68362.7
		(-1.5)	
87/88	229497.5		67349.3

Source: IBGE; IAA; CHESF Inventario Tecnolgia Cana de Acucar Vol. 1.

TABLE 1-23
SUGAR CANE AND BAGASSE PRODUCTION BY REGION
1987/1988 HARVEST

	Sugarcane (1000t)	%	Bagasse (1000t)
Brazil	224497.5	100.0	67349.3
North	264.4	0.1	79.3
Northeast	54438.6	24.3	16331.7
Southeast	146787.3	65.4	44036.2
South	11479.2	5.1	3443.7
Centerwest	11528.1	5.1	3458.4

Table 1-23 shows where this production occurs, with the Southeast and Northeast regions being responsible for almost 90% of all production. Fig. 1-13 shows the areas where the sugarcane is grown throughout the country.

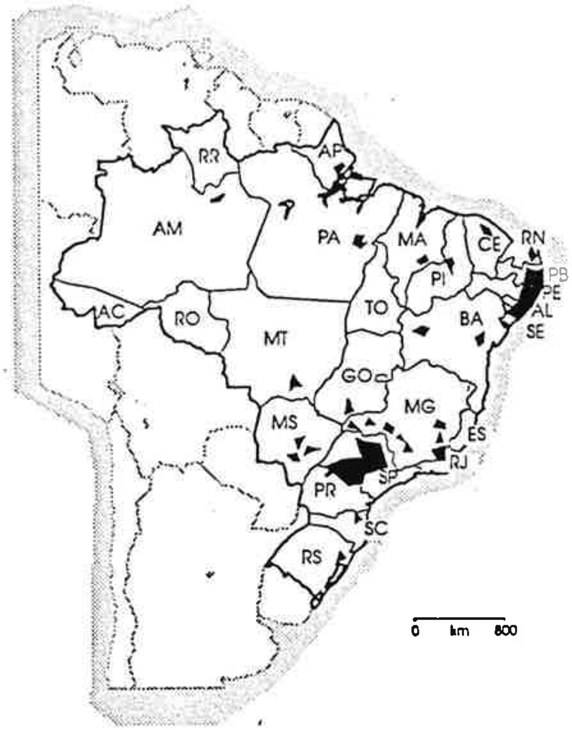


Fig 1.13: Sugarcane plantations - CHESF

Tables 1-24 and 1-25 and Fig. 1-14 indicate the production and consumption of alcohol and its evolution between 1975 and 1988. It also reveals that most of the alcohol is hydrous alcohol, which is used as a liquid fuel substitute for gasoline. It is interesting to note that although the sugarcane production has levelized at 225 million tonnes per year, alcohol production has been steadily increasing.

The "Proalcool Program", the biggest technical success in using biomass for energy worldwide, is being reshaped to comply with today's political and economic environment and mostly, to increase its competitiveness. New policies are expected in this area.

TABLE 1-24
BRAZIL EVOLUTION OF ALCOHOL PRODUCTION

Year	Production (1000 m³)	Average Annually Growth %	Anhydrous %	Hydrous %
1975	625.0			
		40.3		
1980	3396.4			
		18.8		
1985	8052.8		26.3	73.4
		32.5		
1986	10668.6		22.9	77.1
		2.2		
1987	10908.1		19.6	80.4
		6.6		
1988	11630.3		17.1	82.9

Source: IBGE - CHESF Inventario Tecnologia Cana de Acucar

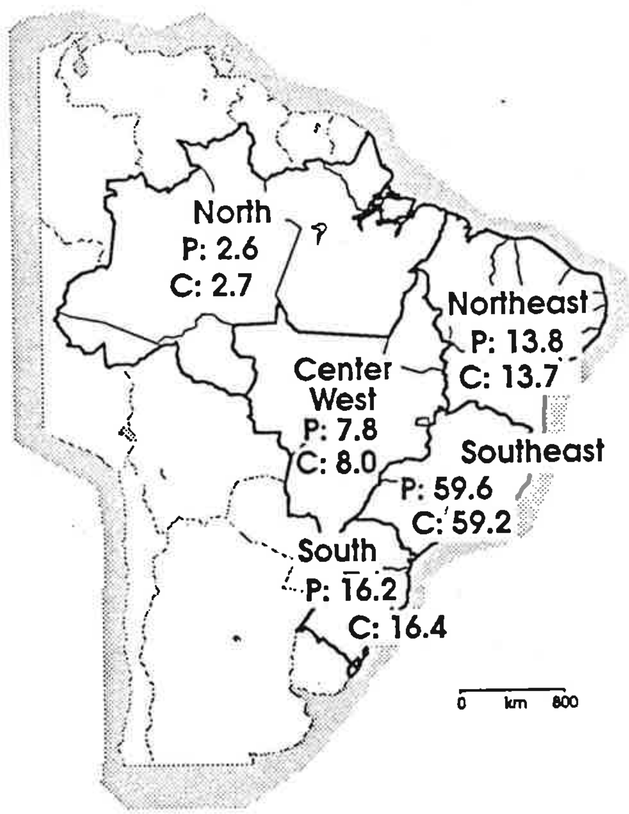


Fig 1.14: Hydrous alcohol production (P) and consumption (C) (%)

TABLE 1-25
BRAZIL HYDROUS ALCOHOL PRODUCTION AND CONSUMPTION - 1988 (1000 m^3)

	Production	Consumption
Brazil	9644.1	9730.9
North	254.3	258.6
Northeast	1326.8	1338.5
Southeast	5754.1	5760.8
South	1559.5	1593.5
Centerwest	749.3	779.5

1.3.4 CHARCOAL AND WOODFUEL

Charcoal and woodfuel have been used for decades, or even centuries, for energy and also as a reducer (charcoal) to produce pig iron for steel mills and other industries, (mainly those in the state of Minas Gerais). Because of the industrial interest in charcoal the country has developed broad experience in the sustainable production of trees on a short rotation basis. This experience has expanded in the pulp and paper industry. Brazil is now among the leaders in the technology of short rotation forestry.

To illustrate the size of operations involved, charcoal production in 1987 is shown in Table 1-26. The major concentration occurs in the Southeast, accounting for about 82% of the charcoal production, with 27% coming from natural forests and 73% from eucalyptus plantations. The area utilized is around 3.8 million ha. (considering 0.25 tc per t wood; 0.37 t wood per m^3ST and 25 m^3ST per ha. per year). Figure 1-15 reveals the production and consumption by region.

TABLE 1-26
BRAZIL CHARCOAL PRODUCTION AND CONSUMPTION AS OF 1987 (t_c)

	Natural Forests	Planted Forests	Total
Brazil	3582277	5619545	9201822
North	38045	253	38298
Northeast	492980	25085	518065
Southeast	2061809	5456692	7518501
South	227672	31136	258808
Centerwest	761770	106380	868150

Source IBGE

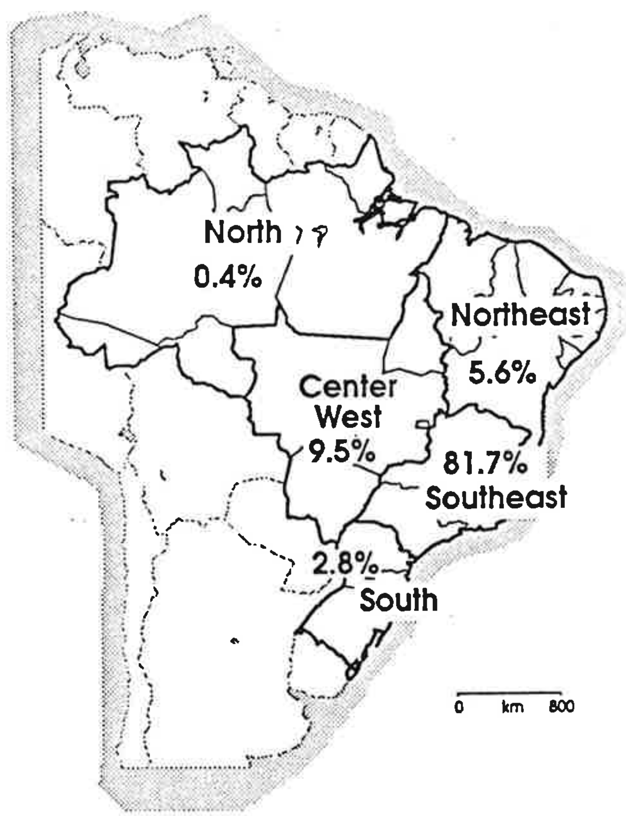


Fig 1.15: Charcoal production and consumption

TABLE 1-27
BRAZIL WOODFUEL PRODUCTION AND CONSUMPTION AS OF 1987 ($1000m^3$)

	Natural Forests	Planted Forests	Total
Brazil	120929.9	45908.1	166838.0
North	10224.5		10224.5
Northeast	59205.7	326.0	59531.7
Southeast	17354.2	35309.1	52663.3
South	21944.5	9218.0	31162.5
Centerwest	12201.1	1055.0	13256.1

It is important to mention that the major users and producers of charcoal, steel mills, operate in a highly competitive environment without any kind of subsidies. In other words, charcoal from planted short rotation forests is a sound economic asset to these companies. It is also important to mention that the actual trend is aimed toward 100% of charcoal production from plantations.

With regard to wood fuel the situation is totally different, since most of it comes from natural forests that are exploited without any technical concern or organization. This is the main reason why most of the country's natural forests are vanishing. This situation is particularly accurate in the Northeast, which appears as a major consumer of wood fuel, as can be seen in Table 1-27. It might be seen also as an example of what kind of result could be expected of the combination of low education and income levels with poor infrastructure.

Fig. 1-16 indicates the woodfuel production and consumption by region on a percent basis.

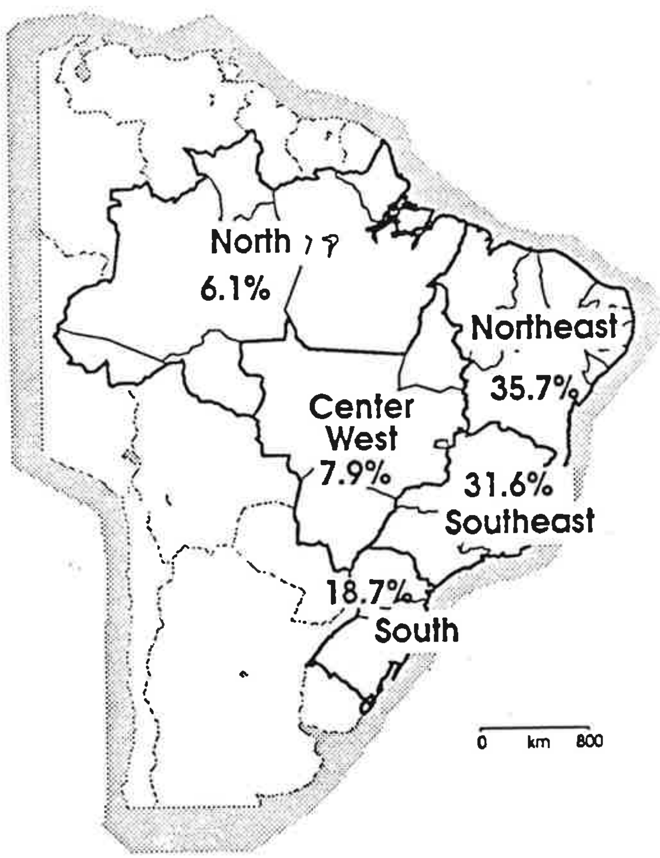


Fig 1.16: Wood fuel production and consumption

1.3.5 COAL PRODUCTION AND CONSUMPTION

Brazil is not a major user of coal, perhaps as a consequence of the poor quality of its coal, 35% to 42% ash. The country reserves are all situated in the South and amount to 35.97 billion t_c, which represents 1713 years of production at the 1988 level.

An indication of what is produced and how it is consumed is shown in Table 1-28, which indicates a huge disparity between production and consumption. The major part being stockpiled and or used as fuel for heat in some industries.

It is important to mention that the indigenous metallurgical coal is a minor part of the total consumption, with the major part being imported. The relationship between indigenous and imported has varied in the range of 29% and 9%, with the lower amounts occurring in the last years (1986 to 1988). (See Table 1-29).

Forty to fifty percent of the steam coal is used to produce electricity in power plants sited close to the mines. The rest is used for heat in various industries. Almost all consumption occurs in the South and Southeast regions.

TABLE 1-28
BRAZIL'S PRODUCTION AND CONSUMPTION OF COAL (1,000 t_c)

Year	Total Coal Production	Metallurgical Production	Metallurgical Consumption	Steam Coal Production	Steam Coal Consumption
1981	17434.1	924.1	1097.8	4557.3	5106.0
1985	24618.8	1095.4	1164.2	6203.3	5991.0
1986	22700.2	1007.5	1164.6	6010.2	7103.0
1987	18115.4	695.5	764.0	5709.7	6987.0
1988	20984.4	835.0	798.0	5947.2	5792.8

Source: IBGE

TABLE 1-29
BRAZIL'S CONSUMPTION OF METALLURGICAL COAL (1,000 t_c)

Year	Total	Indigenous	Imported
1981	4910.4	1097.9	3812.5
1985	9223.8	1164.2	8059,6
1986	10385.2	1164.6	9220.6
1987	9709.7	764.0	8945.7
1988	10344.5	798.0	9546.5

1.3.6 BRAZIL'S ENERGY MIX

In this final section about energy, besides a summary of all the data previously shown the country's production and consumption energy mix will be discussed. The intention is to have a clear idea of what, where and how it is produced and used.

Tables 1-30, 1-31 and 1-32 review the main information presented in the preceding sections and also summarize the conversion factors and the heat values used to estimate the country energy mixes (production and consumption).

Tables 1-33 and 1-34 show the country energy production and consumption mixes. The analyses of these tables, provide some interesting conclusions.

Regarding production, approximately 64% of the energy is produced by renewables sources. Petroleum accounts for 28.7% and biomass, bagasse, charcoal and wood fuel, for 38.8%. Wood fuel alone, is responsible for 18.39% of the country's total energy. It is important to note that most of this production has no support or organization at all, coming from the predatory exploitation of natural forests, which has been the main cause of their near extinction.

TABLE 1-30. BRAZIL ENERGY PRODUCTION SUMMARY (1988)

	Brazil	North	North-east	South-east	South	Center-west
Electricity GWH	231915.0	19486.0	24699.0	122921.0	60971.0	3924.0
Petroleum $1000m^3$	32237.3	13.8	12406.8	19816.7		
Natural Gas 10^6m^3	5844.1	3.4	3352.0	2488.7		
Total Alcohol $1000m^3$	11630.3	324.6	1536.7	6945.7	1942.1	881.1
Bagasse 1000t	67349.3	78.3	17331.7	44036.2	3443.7	3458.4
Charcoal 1000t	9201.8	38.3	518.1	7518.5	258.8	868.2
Wood Fuel $1000m^3$	166838.0	10224.5	59531.7	52663.3	31162.5	13256.1
Coal 1000T. S.C.	5947.2				5947.2	
M.C.	835.0				835.0	

OBS. Coal production includes the portion used for electric generation, that represents 40% of the steam coal (S.C.)

TABLE 1-31. BRAZIL ENERGY CONSUMPTION SUMMARY (1988)

	Brazil	North	North-east	South-east	South	Center-west
Electricity GWh	202349.0	7666.0	30421.0	128480.0	27830.0	7956.0
Petroleum Products $1000m^3$	56866.8	3337.9	8535.0	30076.3	9790.7	5126.9
Natural Gas 10^6m^3	5884.1	3.4	3352.0	2488.7		
Hydrous Alcohol $1000m^3$	9730.9	258.6	1338.5	5760.8	1593.5	779.5
Bagasse 1000t	67349.3	79.3	16331.7	44036.2	3443.7	3458.4
Charcoal 1000t	9201.8	38.3	518.1	7518.5	258.9	868.2
Wood Fuel $1000m^3$	166838.0	10224.5	59531.7	52663.3	31162.5	13256.1
Coal 1000T S.C.	5792.8			2425.4	3367.4	
Nat. MC	798.0			798.0		
Imp MC	9546.5			9546.5		

Notes: - Steam Coal (SC) includes the amount used for electricity generation
- The consumption of SC was allocated as follows: all S.C. used for electricity in the south, the rest (70%) to the Southeast and 30% to the South.

- Anhydrous alcohol is assumed to be included in the petroleum products

TABLE 1-32
CONVERSION FACTORS
DENSITIES AND HIGH HEAT VALVES

	MJ/MWh	HHV MJ/Kg	Dens. Kg/m^3
Electricity	3600.8	--	--
Petroleum		45.22	867
Petroleum Products		45.22	867
Natural Gas		41.24MJ/m^3	--
Hydrous Alcohol		27.84	809
Bagasse		9.45	--
Charcoal		28.47	250
Woodfuel		13.82	350 Kg/m^3st
Coal S.C.		18.84	--
N.M.C.		28.47	--
I.M.C.		33.16	--

Notes:
- Petroleum products used the same values as for petroleum
- Bagasse with 50% moisture

  Woodfuel m^3st stereo cubic meter
  25% moisture air dry
- 1 kwh=3.6MJ 1K cal=4.187 KJ
- Hydrous alcohol figures used for total alcohol differ less than 1% in the energy mix.

Source: Balanco Energetico Nacional 1988 MME Brazil

On the consumption side these figures are slightly different but also elucidative. Renewables account for 48% of the total, petroleum products for 40%, biomass for 31% and wood fuel for 11.5%. Finally, petroleum and coal, metallurgic coal, are the main shortages.

In Table 1-35 is shown a summary of the country's production and consumption of energy per region and again, some interesting conclusions can be drawn. First, the country produces around 80% of the energy consumed. Second, and perhaps the most important, is that the Northeast is the only region to have a surplus of energy; therefore it is the only net exporting region. This is a very important fact that should be considered by the energy policy makers and policy makers in general. Table 1-36 is a survey of the most important information discussed up to this point.

TABLE 1-33
BRAZIL'S ENERGY PRODUCTION MIX - 1988
(1000 GJ or TJ)

	Brazil	North	Northeast	Southeast	South	Centerwest
Electricity	834894.0	70149.6	88916.4	442515.6	219495.6	14126.4
Petroleum	1263702.2	541.0	486346.6	776814.6		
Natural Gas	24101.7	140.2	138236.5	102634.0		
Total Alcohol	261949.3	7311.0	34611.1	156438.0	43742.0	19845.0
Bagasse	636450.9	739.9	163784.6	416142.1	32543.0	32681.9
Charcoal	261975.3	1090.4	19750.3	214051.7	7368.0	24717.6
Woodfuel	806995.4	49455.9	287954.8	254732.4	150733.0	64119.8
Coal S.C	68185.7				68185.7	
M.C	23772.5				23772.5	
Total	4398936.0	129428.0	1214600.3	2363328.4	545839.8	155490.0
%	100	2.9	27.6	53.7	12.4	3.5

Notes: Tables 1-33, 1-34
- Steam coal does not include the portion used for electricity generation.
- Hydrous alcohol density and high heat value were used to calculate the energy content of both hydrous and anhydrous alcohol.
- On the energy consumption, the anhydrous alcohol is accounted for as gasoline blend.

TABLE 1-34
BRAZIL'S ENERGY CONSUMPTION MIX 1988
(1000 GJ or TJ)

	Brazil	North	Northeast	Southeast	South	Centerwest
Electricity	728456.4	27597.4	109515.6	462528.0	100188.0	28641.6
Petroleum Products	2229178.6	130845.7	334572.0	1178991.0	383795.4	200974.5
Natural Gas	241010.7	140.2	138236.5	102634.0		
Hydrous Alcohol	219169.0	5824.4	30147.0	129750.5	35890.4	17556.7
Bagasse	236450.9	739.9	163784.6	416142.1	32543.0	32681.9
Charcoal	261975.3	1090.4	14750.3	214051.7	7368.0	24717.6
Woodfuel	806955.4	49455.9	287954.8	254732.4	150733.0	64119.8
Coal SC	65275.8			45694.5	19582.3	
NMC	22719.0			22719.0		
IMC	316.561.9			316561.9		
Total	5,527,794.0	215,693.9	1,078,960.8	3,143,805.1	730100.1	368692.1
%	100	3.9	19.5	56.8	13.2	6.6

Notes: Tables 1-33, 1-34
- Steam coal does not include the portion used for electricity generation.
- Hydrous alcohol density and high heat value were used to calculate the energy content of both hydrous and anhydrous alcohol.
- On the energy consumption, the anhydrous alcohol is accounted for as gasoline blend.

TABLE 1-35
BRAZIL'S PRODUCTION AND CONSUMPTION OF ENERGY PER REGION (100GJ)

	Production	Consumption	Prod. Cons.
Brazil	4398936.0	5527794.0	79.6
North	129428.0	215693.9	60.0
Northeast	1214600.3	1078960.3	112.6
Southeast	2363328.4	3143805.1	75.2
South	545839.8	730100.1	74.8
Centerwest	155490.7	368692.1	42.2

TABLE 1-36

SUMMARY OF BRAZIL'S GEOGRAPHIC, SOCIAL, ECONOMIC AND ENERGY DATA, 1988

	Brazil	North	Northeast	Southeast	South	Centerwest
Area km^2	8511965 100%	3581180 42%	1548672 18%	924935 11%	577723 7%	1879455 22%
Population (1000 Inhab)	150638 100%	8893 5.9%	42822 28.5%	65559 43.6%	22762 15.1%	10332 6.9%
Average Population Growth Rates 1980-2000	2.1%	3.79%	1.85%	2.13%	1.62%	2.87%
GNP Gross $310-330 billion	100%	3.5%	13.2%	61.3%	16.6%	56%
GNP Per Capita	2200-2300	1335	1042	3164	2473	1826
Energy Prod. (4.4 EJ)	100%	2.9%	27.6%	53.7%	12.4%	3.5%
Energy Consump. (5.53 EJ)	100%	3.9%	19.5%	56.8%	13.2%	6.6%
Illiteracy Rate	25%	10.6%	44.8%	17.2%	17.0%	22.9%
Illiteracy Distrib. %	100%	2.5%	50.9%	30.0%	10.3%	6.3%
Unemployment %	3.85%		5.00%	4.00	3.63%	

1.4 LAND USE OVERVIEW

To have a good understanding of the economical and social aspects of a country, it is important to have basic information about how its land is used; this is even more truthful in the case of Brazil, which is almost a continent by itself.

The numbers resulting from the 1985 Agricultural Land Use Census conducted by IBGE reveal that the land used for agriculture and grazing, 376,286,577 ha., covers 44.2% of the country's area, of which 14%, or 52,380,366 ha., is used for agricultural purposes and the rest, 86%, is used for grazing. In other words, the country uses 6.2% of its area for agriculture and 38% for grazing. Table 1-37 shows the basic information about the use of land in Brazil.

Table 1-38 reveals the distribution of properties by size and also the total area within each property size range. The numbers are very eloquent. A huge concentration of land is shown to be under very few properties. As an example, 61 properties, or 0.001% of the total number have an area which represents 3.3% of the total agricultural and grazing land of the country. On the other hand, properties smaller than 10 ha, which are 3085841 or almost 53% of the total, account for 2.7% of the land. The details, as mentioned, are shown in Table 1-38. Table 1-39 has the information related to number of properties, land area and agricultural jobs per region. What shows up here is the great concentration of agricultural land in the Center West, 31%, but only 5.4% of the properties and 6.3% of the jobs.

This situation is also shown by Table 1-40, which contains the "Agricultural Indexes". The Center West region appears with the highest average property size, 370.2 ha. per property, and the lowest number of employees per ha. On the other hand, the Northeast shows the smallest average property size, 32.6 ha., and the highest number of persons employed per ha. This gives an indication of the degree of mechanization introduced in agriculture in each region. It is interesting to note that the South figures are very similar to the Northeast, although their agricultural culture is very different.

Another interesting aspect is that the index for employees per ha, for the whole country and for the North and Southeast regions, are quite similar to the ones obtained from a comprehensive and detailed study, conducted by CHESF (COMPANIA HIDROELECTRICA DO SAO FRANCISCO), one of the main Brazilian electric utilities, in 1985/86, about the possibility of growing forests on semi-arid lands, to generate electricity. The index of employee per ha. developed in that study, was 0.055 M/ha. More recent information shows that some companies that grow forests for charcoal and pulp and paper have employment rates in the range of 0.03 to 0.04 people per ha.

TABLE 1-37
BRAZIL'S LAND USE - 1985

		% Brazil
Rural Properties	5834779	
Occupied Area (Total) ha	376286577	44.2
Agricultural Area ha	52380366	6.2
Permanent Cultures	9835315	
Short Rotation Cultures	42545051	
Grazing Area ha	323906211	38.0
Employed Persons	23273517	

Source: IBGE 1985 Agricultural Land Use Census

TABLE 1-38
BRAZIL LAND PROPERTY - 1985

Size Range (ha.)	Number of Properties	%	Sum	Total Area Per Size Range	%	Sum
<1	645624	11.0		366408	0.1	
1 to 2	619828	10.6	21.6	835816	0.2	0.3
2 to 5	1049666	18.0	39.6	336493	0.9	1.2
5 to 10	770723	13.2	56.8	5462518	1.5	2.7
10 to 50	1728232	29.6	82.4	39525515	10.5	13.2
50 to 100	438192	7.5	89.9	30153422	8.0	21.2
100 to 10000	566549	9.82	99.62	195468912	63.9	85.1
10000 to 100000	2113	0.03	99.65	45789385	11.6	96.7
>> 100000	61	0.001	99.651	12497783	3.3	99.7

TABLE 1-39
DISTRIBUTION OF PROPERTIES, LAND AREA AND AGRICULTURAL JOBS PER REGION

	Properties	Land Area (ha)	Agric. Jobs
Brazil	5834779	376286577	23273517
North	499775	44884354	2230203
Northeast	2817909	91988105	10374801
Southeast	998907	73614727	4740103
South	1201903	4871066	4463165
Centerwest	316285	117086323	1465195

Source: IBGE 1985 Agricultural and Pasture Census

TABLE 1-40
AGRICULTURAL INDEXES PER REGION

	Ha./Property	Employees/Property	Employees/Ha.
Brazil	64.50	4.0	0.062
North	89.80	4.5	0.050
Northeast	32.64	3.7	0.113
Southeast	73.70	4.8	0.064
South	40.53	3.7	0.092
Centerwest	370.19	4.6	0.013

OBS: Rounded Figures

Another aspect concerning the use of land in Brazil is the preservation of the Amazon forests and the possibility of extensive use of forests for energy purposes, mainly electricity generation in the Northeast region. The legal Amazonia, as officially defined, comprises 9 states Acre, Amapa, Amozonas, Maranhao, Mato Grosso, Para, Rondonia, Roraima and Tocantins and has an area of 4,906,784 km^2, which is about 58% of Brazil.

This region, mostly virgin, has experienced an accelerated occupation process which resulted in a deforestation rate of about 21218 Km^2 per year between 1978 and 1989 (INPA/INPE - deforestation rate in Brasilian Amazonia - 1990), a rate that although much lower than previous estimates, is still worrisome . Certainly, this is one of the major issues, in the land use context, to be addressed by policy makers.

Fig 1.17: Amazon forests and potential northeastern forest plantations

The map in Fig. 1-17 shows the Amazon Forests and also a rough estimate of the area that could be used to grow forests for energy in the Northeast. It is worth mentioning that the idea of using plantations, of short rotation forests, to produce wood for electricity generation, although seriously considered and carefully studied by CHESF, still is in the planning phase. The inherent characteristics of this idea, high rural job rate, high energy potential, competitiveness even at small installed capacities and low investment makes it a strong candidate for future land use in a country such as Brazil, mainly for the Northeast region.

1.5 FINAL CONSIDERATIONS

To close this introductory chapter, it is worth having an overview of the expected future role of biomass on a worldwide basis. It is important to have a clear idea of the main issues that will influence the use of biomass on a mid and long term basis and to know what kind of considerations are present in the most highly industrialized countries, mainly in those with a historical forestry culture, as is the case for Sweden, Finland and even the U.S. It would then be interesting to compare their situation with the one we have in Brazil from the standpoint of biomass use.

The actual world scene shows the increasing importance of, environmental issues. The build-up of CO^2 in the atmosphere, wildlife preservation and the impact of development on virgin areas are examples of issues at constant debate and increasingly present at any new project.

The political world scene is burdened with uncertainties: the unresolved Middle East situation, the major changes occurring in Europe and in the USSR, and a lagging economy in the U.S, are all sources of destabilizing factors which, one way or another, influence the global economy and, as a consequence, energy prices.

On the social side there is widespread pressure for healthier living conditions, which means more education, infrastructure, new jobs and welfare. In the developing countries the debt burden, increasing social pressure for better living standards, and the necessity of building or improving the basic infrastructure, are major factors pressuring for more energy consumption.

Finally, a general movement in the direction of having more direct control and participation in the decisions made by governments and public and even private entities has been observed.

This movement, as seen by the energy sector of most countries, means more energy, produced by cleaner means, at bearable prices, under an unstable environment. These are the main forces pushing for new and imaginative energy solutions, which inevitably will include, for most of the developing countries and even some of the developed, the use of its biomass resources as a prime energy source.

Examples of this new attitude towards energy may be seen in Sweden where new programs for energy conservation and biomass for electricity, with budget of one billion kroners ($ 169.5 million) for the next five to ten years, are being developed; in the EEC with its LEBEN (Large European Biomass Energy Network and JOULE (Joint Opportunities for Unconventional or Longterm Energy Supply) programs, the latter with expenditures 39.3 million ECU over three years (1989 to 1992); in the U.S., where the DOE (Department of Energy) is putting together its new program, Biomass for Power Production whose aim is to give the proper support for research to reach a reliable biomass for electricity system on a commercial basis; and in Finland, with its just announced program to have in the next three years a biomass to electricity system in operation as a demonstration of the gasification-gas turbine technology viability. It is important to mention that the Finnish, Swedish, and American programs are all concentrating on electricity production from biomass via the use of gasification gas turbine technology.

In Table 1-41 is shown a summary of the basic information about the above mentioned programs.

TABLE 1-41
BIOMASS PROGRAMS IN SWEDEN, U.S., FINLAND AND EEC

Country	Program	Budget	Duration (Years)	Aim	Technology
Sweden	Biomass for Energy	1 Billion Kroners	5 to 10	Electricity Production	Gasification Gas Turbine
Finland	BioSTIG		3	Electricity Production	Gasification Gas Turbines
U.S.	Biomass for Power			Electricity Production	Gasification Gas Turbines
EEC	LEBEN		Not Defined	Various Energy Forms	Various
	JOULE	39.3 Million	3	Support New Biomass Energy Projects	Various

In all probability the reason for such renewed interest in biomass is that the biomass can help address most of the issues that are of great concern nowadays. Biomass will probably be one of the answers to cope with the CO_2 build-up in the atmosphere. It also is one of the most promising sources of energy to supply our future needs, and it has already demonstrated its feasibility as an energy source, as proven by the huge Brazilian short rotation forests for charcoal, where significant experience has already been developed and the most advanced agriculture technology is being used successfully.

Biomass is also one of the best answers for creating new rural jobs and for increasing economic development of rural areas. Finally, it is the natural solution to soil protection. Considering all these aspects, the question that surfaces is what would be an appropriate approach to biomass in the future for a country like Brazil, with vast experience in biomass use, where the growing season lasts all year round, with large suitable land areas, and which is eager for new job opportunities, mainly rural jobs.

It seems clear that a very proper posture would be to join the other leading countries in developing the necessary technology to transform biomass into one of its main sources of energy. The viability and benefits of such an advanced posture on biomass use are what we intend to demonstrate in the next chapters of this study.

2. SOME HISTORICAL ASPECTS AND NATURAL FEATURES OF BRAZIL RELATED TO BIOMASS USE.

The introduction of this study gave the background information necessary for understanding the general environment in Brazil. This section gives information more closely related to the role played by biomass in the country's historical context and, with some degree of detail, the main natural features which are directly related to the growth and utilization of biomass.

The first part will deal with some of the most relevant historical aspects of Brazil's biomass use. The second will address Brazil's natural features, such as soil and climate.

2.1 HISTORICAL ASPECTS OF BIOMASS USE IN BRAZIL

The use of biomass in Brazil is as old as the country. It was its first energy source. Around a particular biomass, sugarcane, the country developed its initial economic cycle and society in colonial times.

Sugarcane was introduced by the Portuguese in 1530, with the purpose of supplying sugar to the European market, in what is now known as the state of Pernembuco and at that time named Nova Luzitania. At the same time it was also introduced in Bahia, Itleus, Porto Seguro, Espirito Santo, Paraiba do Sul and Sao Vicente, but it was in Pernembuco where it had its greatest development. In 1549, the establishment of the general government in Bahia provided a great impetus to the development of sugarcane development, resulting in a steady increase in sugar production. At that time the sugar was produced at very small sugar mills named "engenhos".

The evolution of these small and primitive installations in Pernambuco can be seen in Table 2.1. This steady growth placed the country as the world leader in sugar production in the 16th and 17th centuries.

TABLE 2.1 EVOLUTION OF SUGAR MILLS (ENGENHOS) IN PERNAMBUCO.

Year	Number of "Engenhos"
1550	5
1570	30
1584	66
1630	166
1857	532
1914	2756

The period from 1535 to 1650 was one of shining progress for the sugar "industry". After that, the disorganization caused by the war with the Dutch led to a stagnation period that lasted up to end of the 18th century. At that point, when the introduction of a new sugar cane breed (the "cana caina"), the plow, and the use of bagasse to supply the mill's energy needs brought a new era of progress that lasted until 1915, when the production of beet sugar in Europe and the raise of sugar production by many other countries initiated a continuous oscillation of sugar prices in the international market. The competition with the European sugar beet, and the necessity of producing a better quality sugar, has to the rise of new and better organized sugar mills, named "Engenhos centrais". Most of these originated as mergers of the old, small "engenhos". These new enterprises were the origin of modern sugar mills known as "Usinas de acucar".

It is important to note that it was only at the end of the 19th century that bagasse started to be used as a fuel in sugar mills. More or less at the same time occurred the introduction of use of iron crusher mills, giving a significant increase in cane juice extraction and, as a consequence, in productivity.

The history of alcohol production in Brazil follows a parallel path, with significant differences. Its origin goes back to the old "engenhos" where part of the by products of sugar production were distilled to make "cachaca" a spirit beverage with high alcoholic content.

With the increase of sugar production, alcohol (ethanol) began to be produced in larger quantities being used mostly to supply the country's pharmaceutical, chemical and cosmetic needs.

The first remarkable event dealing with the use of alcohol dates back to 1903, when at the First National Conference on Alcohol Industrial Applications (Primeiro Congresso Nacional Sobre Aplicacoes Industriais do Alcool) held in the city of Rio de Janeiro, more than a hundred propositions on production and use of alcohol were made.

During World War I, due to a fuel shortage, alcohol was used to power trucks and cars sucessfully.

In 1919 the government of Pernambuco made the use of alcohol in official cars compulsory. In 1923 alcohol was considered the best solution to prevent the trade of gasoline and kerosene for gold, which was damaging the country's economy. In that same year various car races were promoted to demonstrate the feasibility of alcohol as a fuel. At that time alcohol production was around 125 million liters per year. In 1925 the promotion of two vaces, Rio-Petropolis and Rio-Sao Paulo, with cars using alcohol as fuel were remarkable successes. The year 1927 marked the appearance in the state of Alagoas and Pernambuco of two different alcohol based fuels. The first produced by the sugar mill Serra Grande, named USGA, was a mixture of 79.5% alcohol, 20% ether and 0.5% castor oil. The second, Azulina, was a mixture containing 85% alcohol, 10% ether and 5% gasoline. Both failed due to the Great Western Railways of Brazil, which acting under the interests of oil companies operating in the country, raised the tariff for alcohol and decreased that for gasoline. No counteraction is registered.

To face a production surplus during 1930/31 the federal government, through the decree 18717 of February 2nd established the blend of 5% alcohol in gasoline. During World War II, again severe supply shortages forced its use as fuel for cars and trucks. At that time production reached 650 million liters per year. With the end of the war, the use of alcohol decreased and production remained in the range of 400 to 700 million liters up to 1975 when, on November 4 through the decree 76595 the National Alcohol Program (Programa Nacional do Alcool - Proalcool), was established as a reaction to the huge increases of petroleum prices. The alcohol program was launched with ambitious targets that can be summarized as follows:

- Reduction of regional income disparities
- Increase job opportunities nationally
- Expand the country's industrial base

The response of the private sector, at which the program was aimed, was immediate. The provision of financial resources at little or negative costs, the support of the federal government, and a market eager for the product, made the program a success, as can be seen by the steady increase in alcohol production up to 1985 as shown in Table 2.2 and 2.2A. From 1986 and on, the production stabilized around 11 million m^3 as a result of shortages of investment capital and the disruption of the price policy.

TABLE 2.2 EVOLUTION OF ALCOHOL PRODUCTION

Year	1000 m^3	Year	1000 m^3
75	580	82	5618
76	642	83	7951
77	1388	84	9201
78	2248	85	11563
79	2854	86	9983 (10669)*
80	3676	87	12340 (10908)*
81	4207	88	11630 *

Obs. Source Balanco Energetico Nacional and IBGE * ( ).

TABLE 2.2A EVOLUTION OF SUGARCANE PRODUCTION IN BRAZIL

Year	Production 1000T	Area 1000ha	Productivity T/ha
1932	148629.0	328.2	45.0
1936	18099.4	459.9	39.0
1940	22252.2	564.2	39.0
1944	25148.9	675.6	37.0
1948	30892.6	818.6	38.0
1952	36041.1	919.8	39.2
1956	43975.7	1124.1	39.0
1960	56926.9	1339.9	42.5
1964	66399.0	1519.5	43.7
1968	76610.5	1686.7	45.4
1973	91877.4	1958.9	46.9
	NATIONAL ALCOHOL PROGRAM INAUGURATION		
1976	103173.5	2093.5	49.3
1978	129144.9	2391.5	54.0
1980	148650.6	2607.6	57.0
1982	186646.6	3084.3	60.5
1984	222317.8	3656.81	60.8
1986	239278.3	3951.8	60.5
1987	268584.8	4310.4	62.3
1988	258560.2	4128.9	62.6

In 1979, new increases in petroleum prices reinvigorated the alcohol program aiming. New and more ambitious targets were set. Production reached 14 million m^3 in 1987.

At that time not only the Alcohol program was revised, but new measures were announced, such as the restructuring of petroleum refinery profiles, investments to increase indigenous petroleum production, energy conservation measures, increased energy prices and maximization of petroleum products substitution. Besides all those measures, two new programs were announced, The Vegetable Oil Program (Programa de Oleos Vegetais - Prooleo) and Forests for Energy Program (Programa de Florestas Energeticas), the first with the aim of substituting for 16% of diesel use in 1985.

Although some research work was made at Universities and Technological Institutes, in practical terms both programs remain undeveloped.

The current alcohol program reflects a new revision aiming to increase its competitiveness through the improvement of the sugar mills energy efficiency and their establishment as cogeneration facilities, supplying surplus electricity to the grid.

From the aforementioned some interesting conclusions can be drawn. First, the use of alcohol as a substitute for petroleum products in crisis times is not new. It has been the country's natural and systematic response. Second, the abandoning of the alcohol solution once the crisis is overcome has also been systematic. The most eloquent example of this is the current fierce discussions about the closing of the Proalcool program, in spite of all the investments made ($6.5 billion in the period 1976 to 1985) and results obtained. Third, the program has reached a level of success that is a matter of concern to most oil companies, including Petrobras and thus it is an example of practical experience with a renewable biomass derived fuel that is worthy of observation and analysis by developed and developing countries.

Another biomass source which is of interest in the context of the country's economical and social development, is wood. The abundance and ease with which it could be obtained and used made wood the prime and natural energy source in the country's early days. This abundance and facility of use has probably led to the lack of organized use, almost no technology (or no technology at all), and to the predatory exploitation of wood as a fuel, a situation that has persisted up to present times. It is signficant that it was more than 350 years before the sugar mills began to use bagasse as a substitute for wood fuel, even though it is a by-product of sugar cane processing. The use of wood for energy or as an industry feedstock may be classified in three large areas, woodfuel, wood for charcoal and wood for pulp and paper. The last two were established more recently, experiencing a more intense and accelerated development in the last 30 to 40 years. Contrary to woodfuel, these are very well organized areas, where the most advanced technologies for wood production are used, research and development are constant, highly skilled and trained laborers are employed, and a huge organized support infrastructure exists. These are the main reasons for the indisputable success of most of the companies operating in this area, a success reflected in the steady increase in productivity.

Nowadays average productivities in the range of 30 solid cubic meters per hectare per year (sol m^3/ha.y) to 40 sol m^3/ha.y (15 dry t/ha.y to 20 dry t/ha.y) or even higher may be easily found for forests grown under these conditions.

On the other hand, woodfuel as aforementioned, remained an unsupported, disorganized and mostly predatory activity. Bakeries and small ceramic installations, the main users, are beginning to suffer increasing shortages of wood.

In Table 2-3 is shown a profile of wood consumption in 1987 and we see that woodfuel accounted for more than 45% and wood for charcoal for 29%. Together they are responsible for around 75% of the total wood used in the country. Plantations represent 41.4% of the total production or 151.5 million stacked (st.) cubic meters, which means, if we consider an average productivity of 30 st. m^3/ha.y, an area of 5.05 million ha, of which wood for charcoal covers 1.92 million ha and for pulp and paper, 1.11 million ha, adding to 3.03 million ha.

Considering that the investment costs to plant one hectar is in the range of US $800 up to US $1100, it means a total investment between US $ 4.04 billion and US $5.55 billion, of which wood for charcoal and for pulp and paper accounts for 60%.

The main consumers are the Southeast and Northeast regions with 44% and 20% respectively. It is important to note that 78% of the wood consumed in the Northeast comes from natural forests, which has had a devastating effect on the regions forest cover. Currently natural forests represent less than 4% of its area.

Another interesting aspect of wood use is seen in Table 2-4 where we find the evolution of wood participation in the country's energy consumption mix between 1970 and 1987. It shows that the participation of biomass has decreased from 47.3% to 28.2% and in the same period wood's share has declined from 42.6% to 17.0%, with a corresponding increase of sugar cane products' share in the total.

TABLE 2.3 BRAZIL WOOD PRODUCTION 1987 (1000 m^3)

		Brazil	North	North East	South East	South	Center West
Charcoal	N	47764.0	507.3	6573.1	27490.7	3035.6	10156.9
Wood	P	57636.4	2.6	257.3	55966.0	319.3	1091.1
	T	105400.4	509.9	6830.4	83456.7	3354.9	11248.0
Woodfuel	N	120929.9	10224.5	59205.7	17354.2	21944.4	12201.1
	P	45908.9		326.0	35309.1	9218.0	1055.0
	T	166838.0	10224.5	59531.7	52663.3	31162.4	13256.1
Logs	N	45743.9	24606.1	8659.5	1278.4	7866.6	3333.3
	P						
	T	45743.9	24606.1	8659.5	1278.4	7866.6	3333.3
Pulp&Paper	N						
Wood	P	33419.1	1166.9	324.3	17250.6	14600.7	76.6
	T	33419.1	1166.9	324.3	17250.6	14600.7	76.6
General	N						
Purpose	P	14516.5		178.0	6741.6	7341.2	255.7
Wood	T	14516.5		178.0	6741.6	7341.2	255.7
Total		365917.9	36507.4	75523.9	161390.6	69325.8	28169.7
%		100	10.0	20.6	44.1	17.6	7.7

Notes for Table 2.3:

1. Rounded figures
2. To convert charcoal to st. cubic meters of wood the following conversion factors were used
   - -0.25 T. of charcoal per T of wood
   - -0.30 T. of wood per st. cubic meter for natural wood
   - -0.39 T. of wood per st. cubic meter
3. St. cubic meter a volume of 1Mx1Mx1M full of wood logs.
4. Conversion factors source: Balance Energetico Nacional.88
5. N - Natural wood
   P - Plantations
   T - Total Wood

Source: IBGE

TABLE 2.4 BIOMASS SHARE OF BRAZIL CONSUMPTION ENERGY MIX

Year	Sugar cane products + Wood + Charcoal (%)	Wood & Charcoal (%)	Total Brazil Energy Consumption (1000 TJ)
70	47.3	42.6	3376.7
72	42.3	37.4	3873.4
74	37.2	32.6	4470.7
76	32.4	28.2	5034.9
78	29.1	23.4	5686.7
80	28.6	20.3	6274.1
82	28.6	20.0	6489.7
84	30.0	20.0	7396.0
86	27.8	18.2	7903.3
87	28.2	17.0	8174.0

Source: IBGE
Obs.: Petroleum high heat value 10800 Mcal/t or 45230 MJ/t
TJ: Tera Joules10^{12} Joules
The conversion of hydroelectricity to petroleum equivalent was made using the factor 0.29 tpe/MWh.

As expected this increase is a direct result of the National Alcohol Program. It is also seen that, in absolute figures, the amount of wood energy produced has remained constant. Finally, Tables 2.5 and 2.5A show the evolution of wood and charcoal production in Brazil between 1961 and 1987.

Although the nature of the available data is clearly changed over time, the analysis of the data lead to some interesting conclusions. Excluding 1980, which lacks figures for natural wood and charcoal production, there is a clear steady growth in production of wood and charcoal, averaging 3.3% and 8.8% per year respectively. Natural wood production has varied between 107 and 140 million st. m^3, with declining production in the last years. The share of planted wood in the total wood production, although still low, has been increasing, reaching 36% in 1987.

TABLE 2.5 BRAZIL EVOLUTION OF WOOD AND CHARCOAL PRODUCTION

Item		61	63	66	69	73	75	80	85	86	87
Charcoal Wood 1000 t	N	929	1211	994	1415	1826	2364		3515	3365	3582
	P						999	670		2010	5619
Woodfuel 1000st.m^3	N	107258	123599	130685	128334	132581	122123		139730	126136	120930
	P					23920	30961		46404	45908	
Logs 1000 st. m^3	N					36665	28157		42884	44670	45744
	P						22383	41827			
Pulp/paper Wood 1000 st. m^3	N										
	P									29538	33419
Gen. Purp. Wood 1000 st. m^3	N										
	P									11145	14516
Charcoal Total		929	1211	994	1415	1826	3363	670	3515	5375	9201
Wood Total		107258	123599	130685	128334	169246	196583	72788	182614	257893	260517

TABLE 2.5 A BASIC DATA ABOUT WOOD PRODUCTION IN BRAZIL

Source: IBGE Statistics (Various Years) Rounded Figures

Year	Logwood (1000 m^3st)	Woodfuel (1000 m^3st)	Charcoal (1000 T)	
1961		107257.5	928.9	
1962		112932.5	1047.7	
1963		123598.8	1211.1	
1964		129606.9	1037.4	
1965		135265.5	984.1	
1966		130684.8	993.6	
1967		135730.0	905.9	
1968		131074.0	975.2	
1969		128334.0	1414.6	
1970		134804.0	1589.6	
1973	36665.0	132580.6	1826.0	N
1974	25958.8	120991.2	2085.5	N
	17992.4	18405.4	714.1	P
1975	28156.8	122122.7	2363.9	N
	22382.5	23919.7	998.8	P
1980	41827.2	30961.1	670.4	P
1984	35321.6	26680.8	1610.3	P?
1985	42884.2	139729.8	3514.8	N
1986	See Table 2.5			
1987	See Table 2.5			

To give a clear idea of how impressive is the participation of wood plantations in the steel industry, the evolution of pigiron and steel production in Brazil is shown in Table 2.5B and 2.5C.

In the period 1980 to 1989 pigiron production has evolved from 12.68 million tons to 25.45 million tons or approximately 100% and the pigiron produced using charcoal has remained constant at around 38%. In the same period steel production has evolved from 15.34 million tons to 25.02 million, or 63%. Steel production using charcoal has averaged 19% of the total production and steel produced using coke from mineral coal, 60%. This is clear evidence of the successful use of biomass in an entrepreneurial environment. The significance of this success is not fully appreciated inside the country and mostly ignored outside.

TABLE 2.5B EVOLUTION OF PIGIRON PRODUCTION IN BRAZIL

Year	Using Mineral Coal		Using Charcoal		Total
	10^6t	%	10^6t	%	
1980	7.74	61.0	4.94	39.0	12.68
1983	8.09	62.5	4.85	37.5	12.94
1986	12.62	62.3	7.64	37.7	20.26
1989	15.75	61.9	9.70	38.1	25.45

Source: Abracave

TABLE 2.5C EVOLUTION OF STEEL PRODUCTION IN BRAZIL

Year	Using Mineral Coal Coke	Using Charcoal	Others	Total
1980	8.68	3.12	3.54	15.34
1983	8.53	2.84	3.30	14.67
1986	13.08	3.47	4.69	21.24
1989	15.75	4.69	4.58	25.02

Source: Abracave

The results of biomass use in Brazil, as almost everything else, has good and bad aspects. A clear benefit has been the creation of a large number of jobs. It is estimated that planted wood is responsible for approximately 200,000 jobs and the sugar cane for 600,000. The improvement in silviculture technology is well recognized. The country is a global leader in forestry development.

The sugar cane agroindustry is the best, or among the best, in the world. Alcohol and charcoal are proven energy sources.

The development of biomass on a sound, professional basis has contributed to increased incomes of many families and to improved national income distribution. The biomass activity has lead to a better organized society, which has lead to a stronger enforcement of social demands. On the other hand the predatory use of natural wood has devastated the natural forests of the country, contributed to soil erosion and led to the carry over of sediment into many rivers, impairing their use as a water source. The improper disposal of stillage in many areas where sugar mills or distilleries are located has been disastrous, reaching the point where the opposition to this practice was so powerful that the situation was rapidly remedied.

The initial credit conditions for the Alcohol program -- large money supplies at very low cost -- and the colonial sugar cane culture, have impaired the entrepreneurial development of enterprises, with subsides still present. But the social development of the Brazilian society, which has imposed new controls over industrial activity as a whole, the increasing ecological knowledge, the existing pressure to stop subsidies of any kind, the practical fact that little natural wood is left at reasonable distances, and the power given to environmental agencies to control pollution, have led to a change in attitude from executives and industrialists. New and better processes were and are being developed. Nowadays the use of stillage as a fertilizer is a common practice.

More wood has been planted and its share of the total wood production has increased year by year. The recuperation of environmentally damaging tars in the charcoaling process is fully implemented by most companies.

New uses for bagasse are being discovered, and its use as a fuel for electricity is growing. All this suggests that biomass can be used in an environmentally safe way, as soon as a broad understanding is developed of the context in which it is involved technology is available, and most importantly, better human resources are provided. All this is intimately related to better education, which leads to social progress and, as a consequence, to a better balanced cost-benefit relationship.

This overview of the use of biomass in Brazil makes clear the importance of this natural resource in the country's history. It also shows that its use has been the basis for some very successful enterprises, which provides confidence that future uses of biomass on a broader basis, such as electricity production, may be encouraged with the sureness of high chances of success.

If we match the vast previous experience with the inherent benefits of wood growth, the conclusion is that biomass is a resource which the country can and should rely on in future development programs.

2.2 SOIL AND CLIMATE CONDITIONS PREVAILING IN BRAZIL

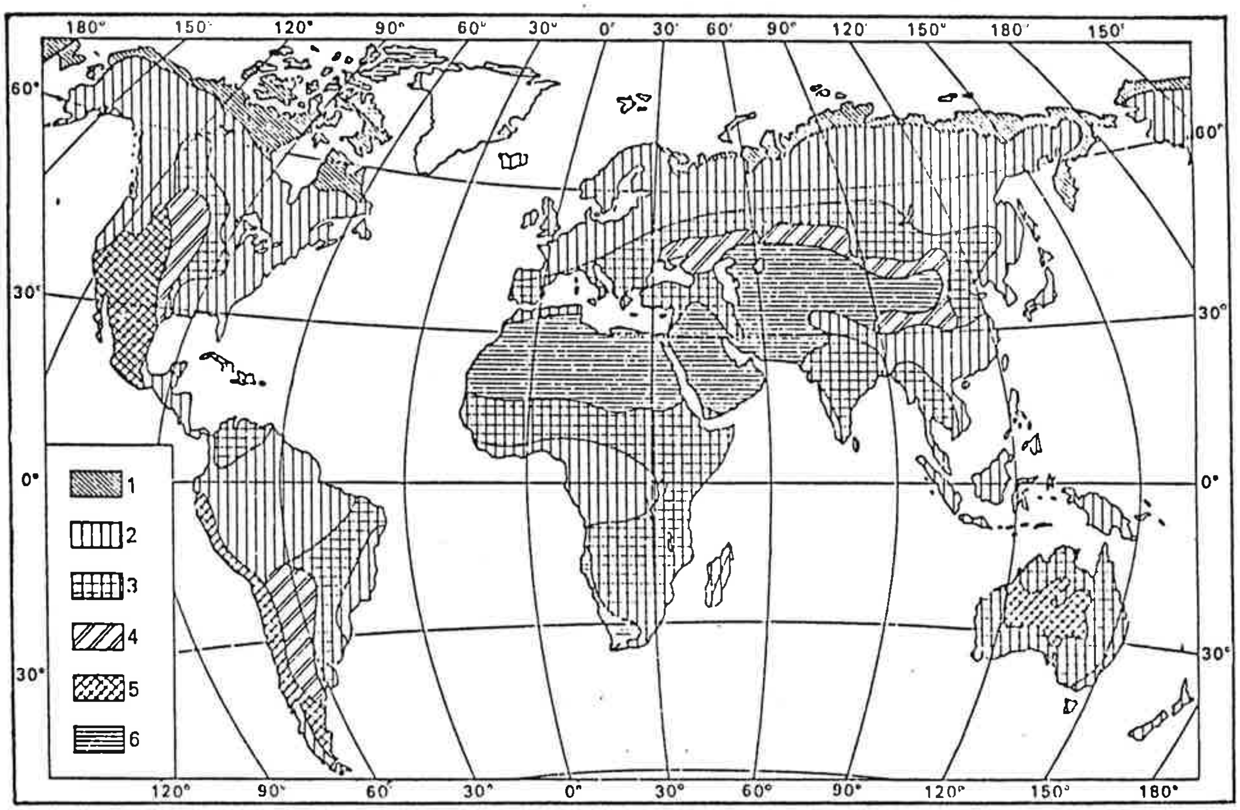
This section describes some of the basic natural features of Brazil that are related to the growth of biomass: soil, temperature, insolation, precipitation and some interrelations among them.

All the information about soils is based upon UNESCO, Soil Map of the World - 1971 and the studies published by Soviet soil scientists, in the book "Soils of the World" by M.A. Glasovskaya, 1973. More detailed studies performed by EMBRAPA (Empresa Brasilerna de Pesquisa Agropecuaria) were not used, because were judged to be out of the scope of the analyses that will be presented in this section, although, they were the basis for the study made by CHESF about the potential of growing biomass in the Northeast semi-arid region.

2.2.1 SOIL COVER OF BRAZIL

Soil cover in any place is related to the basic materials existing in that particular region, the geological processes that have occurred over the years or ages, and climate patterns, mainly temperature and moisture, which form what is known as wet patterns.

The largest soil geographic units of the world are the soil geochemical fields or associations, distributed over the main wetting zones as seen in Fig. 2.1.



Soil-geochemical fields:

1—field of acidic ulmate-fulvate gleyey siallitic soils; 2—field of acidic ulmate-fulvate siallitic ferrallitic and ferrallitic soils; 3—field of fulvate humate acidic-alkaline and neutral-alkaline siallitic and ferrallitic soils; 4—field of neutral-alkaline humate siallitic and ferrallitic-calcareous soils; 5—field with combination of alkaline calcareous and calcareous-gypsic siallites with neutral-alkaline relict fersiallitic soils; 6—field showing predominance of alkaline, calcareous, calcareous-gypsic and saline soils.

Fig. 2.1

Under this broad classification, the soil cover of Brazil is characterized by fields 2,3 and a small part under 4 (see Fig. captions).

Most of these soils were formed in the presence of organic substances, alkali soluble, derived of decaying vegetables matter, mostly yellow, reddish, sandy and with the presence of iron, that may present an acid, alkaline or neutral character.

Most of Brazil soils may be classified under the acidic and acidic-alkaline subaerial associations, which means soils formed under atmospheric conditions with an acid and acid-alkaline character.

The acidic subaerial are mostly of the acidic clayey generation belonging to the Fulvo ferrallites family, meaning soils with a clayed texture, predominantly yellow-reddish color, with the presence of iron and having an acid character.

The acidic-alkaline subaerial belong to the weakly acidic humic acidic-alkaline eluvial-illuvial generation and to the Ferrozeums family, meaning soils formed under weathering atmospheric conditions with a weak acid character, derived from humic acids, and also soils with acid or alkali characteristics, with the presence of iron oxides and formed from disintegrated rock material and or from soluble salt colloid deposition and small mineral particles and having varied colors, going from red to pink or orange. Tables 2.6 and 2.7 show the formation conditions of the Fulvo ferriallite and Ferrozems families soils, and Figures 2.2 and 2.3, their occurrence throughout the world.

The next step in the soil classification and which is of greater interest in practical terms, is the soil type within a soil family. Tables 2.8 and 2.9 show the main soil types of the two aforementioned families. It is important to add some specific comments about the red ferrallitic and alferritic soils, which are widespread in the Brazilian highlands.

Most of the red-yellow ferrallitic soil properties are retained in the red ferrallitic soil. Their clay material have the same kaolimite-halloysite composition containing gibbsite, low absorption capacity and fulvate humous composition.

TABLE 2.6 CONDITIONS OF FORMATION OF FULVO FERRIALLITES FAMILY SOILS

1 - Humid and warm or hot climate.
2 - Paremt material of fersiallitic allitic, ferriallitic or allitic nature, poor in bases with mostly kaolinite, in the clay composition.
3 - Massive rocks, rich in minerals containing iron and aluminum, with surfaces old enough to permit the ferrallization process.
4 - Vegetation, subtropical, tropical and equational wet forests.
5 - Free drainage and low erosion conditions.

TABLE 2.7 OCCURRENCE AND FORMATION CONDITIONS OF FERROZEMS FAMILY SOILS

1 - Equatorial monsoon belt with long dry periods.
2 - Vegetation, dry savannas, xerophobia tropical thin forests, shrub formation and thorny forest.
3 - Uniformly high temperatures and moistening, with sharp changes from season to season, not permitting the ferrallization process to develop.

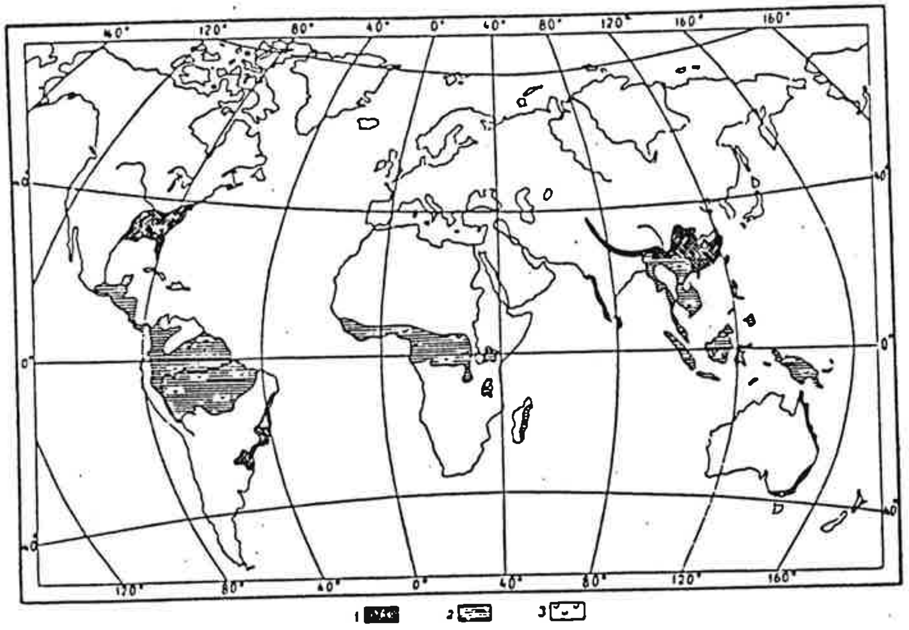
TABLE 2.8 TYPES OF SOILS OF FULVO FERRALLITE FAMILY

1 - Yellow soils and red soils of humid subtropical forests (red-yellow soils, oxisols, acrisols).
2 - Reddish-yellow, reddish-brown, brown ferrallitic and allitic soils of permanently humid tropical and equatorial forests (red-yellow and frown latosols, sols ferrallitiques, ferralsols, kaolisols).
3 - Red ferrallitic and red alferritic coils of tropical park forests, thin forests and secondary tallgrass savanna (ferrisols, xeroferralsols, lateritic red earth).

TABLE 2.9 TYPES OF SOILS OF FERROZEMS FAMILY AND PARTICULAR DENOMINATION

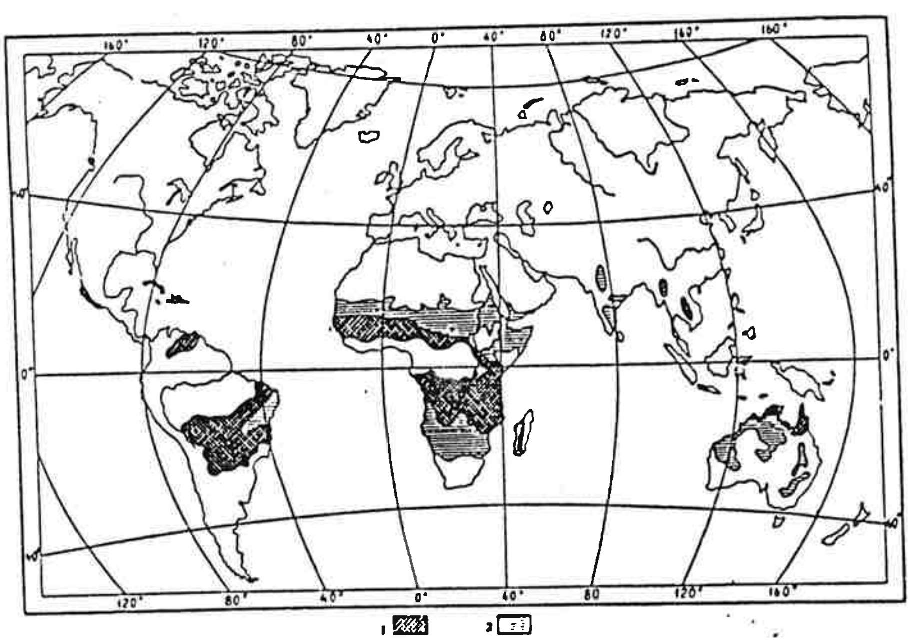
1 - Red earth, with or without calcareous horizon (Australia).
2 - Ferruginous tropical soils (Africa).
3 - Ferralsols of semiarid tropic (Brazil).
4 - Reddish-brown ferritic soils of dry savannas and reddish-brown ferritic soils, of xerophitic tropical and thin forests (soilmaps)

OBS. These are one of the least studied soil groups of the world.



Areas of occurrence of fulvoferrallites.
1—red and yellow soils; 2—red-yellow and dark-red ferrallitic soils; 3—eluvial-podzolic soils.

Fig. 2.2



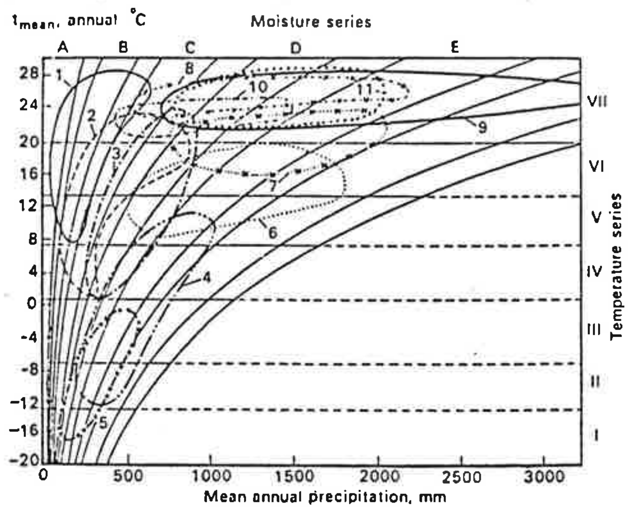
Areas of distribution of ferrozems (red and reddish-brown ferritic soils of dry savannas and reddish-brown ferritic soils of xerophytic tropical forests and thin forests). 1—regions of sporadic occurrence of ferrozems among ferrallitic soils; 2—regions of predominance of ferrozems.

Fig. 2.3

During long dry seasons in regions where trees are sparse, intense drying and heating occurs, resulting in the dehydration of iron oxides, with the appearance of dark red color in the top soil horizon.

In these soils quite often, the iron oxides are present in the form of 3.5 mm conglomerates. In soils with large quantities of these conglomerates, the term lateritie is added to its name. The lateritie ferrelsols, by direct action of the solar rays and over heating conditions, suffers a rapid mineralization of its organic matter and very intense dehydration of its iron oxides, giving them a sandy nature, decreasing its absorption and normally low water retaining capacity and impairing its fertility. These are soils with low nitrogen and phosphorous contents. The rational use of these soils requires anti-erosion, anti-deflation, to prevent the destruction of the top humus layer, and solar protection measures.

Regarding the Ferrozems soil agricultural use, erosion protecting measures, application of fertilizers and maximum retention of soil moisture are required. In Fig. 2-4 we see the types of soil with great probability of occurence, under the moisture and thermal conditions prevailing in Brazil. It shows that only podzolie and tundra soils are less likely to occur, but as will be seen ahead, even areas of podzolie soils are found in the country.



Climatic areals of principal types of soil of the world in moisture-thermal system of coordinates (after V.R. Volobuev, 1963):

Areals: 1—sierozems and soils of deserts; 2—chestnut soils; 3—chernozem soils; 4—podzolic soils; 5—tundra soils; 6—brown forest soils; 7—red and yellow earths of subtropics; 8—laterites; 9—tropical red earths; 10—slightly leached soils of arid deserts; 11—reddish-brown soils of savanna.

Fig. 2.4

The map of Fig. 2-5 "The global scheme of soil sectors and soil regions" exhibits the main soils of the world, including those in Brazil, which are underlined in the legend. Table 2-10 gives the soil microstructure of each soil region shown in Fig. 2-5, and it is clear the predominance for the Tropical and Subtropical belts of low quality soils with a high incidence of laterites.

Concluding this overview of Brazil's soil cover, a summary of the predominant occurrences is made. A more detailed presentation is found in the Appendix A-2-1, which contains a list of the main soil types, its occurrence per geographical and geomorphological region and the suitability of the main soil covers, based on the UNESCO study "SOIL MAPS OF THE WORLD - SOUTH AMERICA, 1971".

The main conclusion that may be taken from all this information is that most of Brazil soils have low fertility, probably more than 75% of the country's soils are in this classification. Approximately 10% of soils occur in semiarid conditions, where water is the main limitation. The best soils are encountered in parts of the Northeast, South, and Southeast geographical regions, accounting for approximately 15% of the total cover.

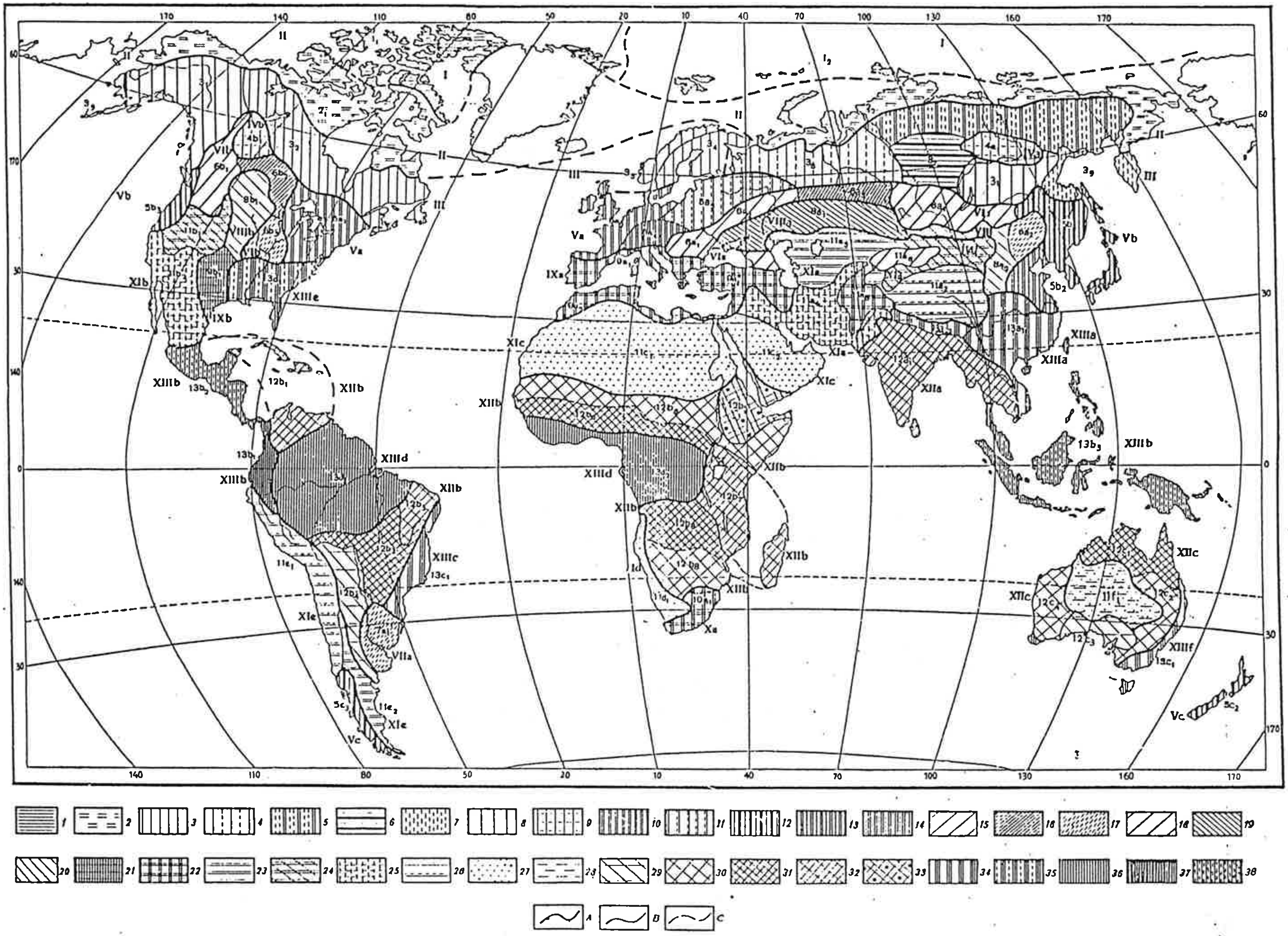


Fig. 2.5

TABLE 2-10: ZONAL SOILS OF PLAINS ACCORDING TO SOIL-BIOCLIMATIC BELTS

Soil-bioclimatic Belt	Zonal types of soil
Polar	1-Arctic; 2-tundra
Boreal	1-sold-course humus and sod-peat; 2-gley-frozen taiga and frozen illuvial-humus taiga soils of the northern taiga and sparse forests; 3-acidic frozen taiga and podolized soils of the central taiga; pale yellow-frozen taiga soils of the central taiga; 4-glye-podzolic soils and podzols of the central taiga; 6-sod-podzolic soils of southern and larch-conifer forests; 7-pale yellow sod-podzolic soils of confier-broad leaved forests; 8-acidic nonpodzoliezed forest soils of conifer-broad leaved and broad-leaved forests; 9-gray forest soils
Sub-boreal	1-brown forest soils; 2-chernozemlike prairie soils (brunizems); 3-steppe chernozems; 4-chestnut soils of arid steppes; 5-brown semidesert soils; 6-gray-brown desert soils
Subtropical	1-yellow-brown soils of broad-leaved forests; 2-zheltozems and krasnozems of moist subtropical forests; 3-reddish-black soils of subtropical prairies; 4-cinnomon-brown soils of subtropical xerophytic forests and shrubs; 5-chernozemlike soils of subtropical steepes; 6-gray-cinnamon-brwon soils of subtropicals-shrubs steppes; 7-sierozems of stubtropical semideserts
Tropical	1-reddish-yellow lateritic (allitic, ferrallitic, alfaerritic) soils of perpetually wet tropical forests; 2-red laterite (ferrallitic, alferritic, ferritic) soils of seasonally wet tropical forests and tall grass savanna; 3-brownish-red lateritized (alferritized, ferritized) soils of xerophytic tropical forests and shrubs; 4-reddish-brown soils of arid savanna; 6-soils of tropical deserts

Source: Soils of the World, M.A. Glazovskaya, Vol II

SUMMARY OF BRAZIL SOIL COVER

1. Determinant factors of Brazil soils

   -Expanse of South America in the meridonal direction
   -The Andes mountains at the west coast
   -Prevalent east-west movement of high moisture air from the Atlantic ocean in the equatorial tropical and subtropical belts
   -The cold Peruvian current off the Pacific coast
   -Old leveled surfaces with thick ferrallitic, often highly lateritized weathering crust in the equatorial and tropical belts
   -Occurence of agradational plains in the subtropical belt
   -Presence of active volcanos in the northern and southern Andes

2. Brazil soil regions (SR) and districts (SD)

   (SR) Amazon (North)
   - Amazon lowland (SD)
   - Guyana Highland (SD)
   - Brazilian Highland (SD)
   - Atlantic (SD)

   (SR) Atlantic Wet Forest (Southeast-South)
   - Northeastern Brazilian (SD)
   - Southwestern Parana-Uraguay (SD)

   (SR) Central Brazilan (Centerwest)

   (SR) East Brazilian (Northeast)

3. Main soil types of Brazil soil regions (SR) and/or soil districts (SD)

Amazon lowland (SD) North Geographical Region	Yellow ferralltic ground water laterite, bog soils, and sandy podzols. The predominant yellow

	ferrallitic have low iron oxides and gibbsite contents, are very acidic, highly saturated and often of light texture and have low natural fertility
Guyana Highland (SD) North Geographical Region	Red-yellow ferrallitic, red-yellow ferrallitic podzolic, laterites and thin stony soils
Brazilian Highland (SD) North Geographical Region	Redish-yellow, dark red ferrallitic and quartz sandy soil
Atlantic (SD) North Geographical Region	Maritme acidic solonchak bog and sandy soils
Northeastern Brazil (SD) Northeast Geographic Region Southeast Geographic Region	Very poor reddish-yellow podzolic ferrallitic soils
Southwestern Parana-Uraguay(SD) Geographical Region	Dark brown ferrallitic and South and fersiallitic soils, acidic and highly unsaturated, with high adsorbed aluminum content and thick humus horizon. Reddish black soils (rubrozems). Dark ferrallitic and fersiallitic soils. Poor podzolic red-yellow soils
Central Brazilian (SR) Center West Geographical Region	Cerrado phase soils-red and dark red ferrallitic soils. Red and yellow, acidic sandy soils (quartz regosols). Northern part

	of the region. Red ferrallite with iron couseretions. Northeastern part of the region- Laterites and ferrallitic, poor and low fertility soils. Southern part of the region- dark red ferrallitic (terra roxa legitima, reddish-brown ferrallitic soils (terra roxa estuturada)
East Brazilian (SR) Northeast Geographical Region	Highly leached poor ferrallitic soils on plateaus. Eastern part of the region, red brown soils and ground water laterites. Sand dunes and saline soils, in some places and depressions.

4. Brazil surface area distribution per altitude

Altitude (m)	Area (km^2)	%
Lowlands	3489553	41.0
0 to 100	2050318	24.1
101 to 200	1439235	
Highlands	4976145	58.5
201-500	3151615	37.0
501 to 800	1249906	14.7
801 to 1200	574624	6.8
Highest areas		
more than 1201	46267	0.5
TOTAL	8511965	100.0

Source: IBGE - Anuario Estatistico

2.3 BRAZIL CLIMATE PATTERNS

Beyond soil cover, the climate is another very important natural characteristic influencing many aspects of a country's life. History, culture and people's character are influenced by climate conditions. Once we turn to agriculture and growth, a good knowledge of climate patterns is mandatory. In order to show comprehensive information about Brazil's climate, covering its most important aspects -- temperature, rainfall, insolation and regional climatic characterization -- we resorted to the "Brazil Climatologic Atlas", edited by Agriculture Ministerium. In spite of being a relatively old document (the last issue was 1969), it is perhaps the most broad and comprehensive study published on Brazil's climate patterns. From a total of 100 maps we selected 10 that are shown in Appendix-2-2.

The main climatic information, included in Table 2-11, indicates a country with mild temperatures, high insolation, dry and wet areas, semiarid and rainforest climates. The semi-arid is situated in the Northeast region whereas the rain forest is in the North. The South and Southeast regions have a subtropical climate that is close to temperate and the Center West is intermediate to these, with very distinct dry and wet periods.

TABLE 2-11 BRAZIL CLIMATE

Temperature Annual Average	14°C to 26°C
Temperature Amplitude Annual Average	6°C to 16°C
Insolation	1600 h/y to 3000 h/y
Relative Humidity Annual Average	65% to 90%
Rainfall Annual Average	500 mm/y to 3500 mm/y
Rainy Days Annual Average	30 to 240
Effective Rainfall (Thornwaite index)	16 to 128 Semiarid Rainforest
Ratio of Rainfall to Evaporation (Annual Average)	0.5 to 2.0

3. BIOMASS TECHNICAL, ECONOMICAL, ENVIRONMENTAL AND SOCIAL ANALYSES*

To understand the role that biomass plays in Brazil's economy it is important to have a broad knowledge of the whole process involved in biomass production, conversion, and end product, from the technical, economical, environmental and social standpoints.

This chapter intends to show the main parameters related to those aspects and their inter-relationships for three of the most important agro industries regarding the present and possible future uses of biomass for energy in Brazil. Those are sugar cane, wood plantations and vegetable oil (palm oil) producing crops. The idea is to make an analysis of the physical flow inherent to each selected biomass, from the implantation phase up to its end products, showing the main parameters involved in each phase and relating to each of the aforementioned aspects.

3.1 OVERVIEW OF BRAZIL'S MAIN CROPS AND CROP RESIDUES

A summary overview of Brazil's major crops and crop residues is shown in Table 3.1. It is seen that the largest area is used to produce Maize (corn), followed by natural wood and soy beans. It is important to mention that the area used to extract natural wood is estimated, since its exact size is not known. The area used for maize is more that 3 times greater than for sugar cane and 2.5 times that for planted wood, respectively.

Looking to the production values, sugar cane appears as the first in the rank, with almost US $2.8 billion, seconded by coffee and natural wood. A third interesting aspect is the relationships among revenue per hectare for each crop. Orange generates by far the most revenue per hectare, followed by coffee and sugar cane, the last of which is surprisingly close to what can be earned growing cassava. Of course these figures give only an indication of the total revenue for a particular year, it is interesting to have a rough idea of each crop's behavior and how it relates to others.

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*All tables in Chapter 3 appear at the end of the chapter.

Table 3.2 shows the estimated residue production for each crop, its energy content, possible uses, applicable conversion technologies and present level of utilization for energy.

The largest quantity of residue is produced by sugar cane tops and leaves. Next comes maize stalks and cobs and rice husks. The total energy content of residues amounts to 2,463,629 TJ, which represents 56% of the country's energy consumption. Not counting what already is in use, the remaining energy amounts to 1.5216090 TJ or 35% of the country's energy consumption in 1988.

Most of the residues are not utilized today. They remain in the field or are disposed of without producing any economic revenue, beyond the disposal costs.

Table 3.3 shows where the main crops are produced in the country. It is interesting to understand the notation used in this table, in order to have a better comprehension of the information it contains. A producer means that some production occurs in the indicated state. Main producer designates states where approximately 10% to 20% of national production occurs. Supermain producer means that more than 35% of the particular crop is produced in that state. In some extreme cases, it goes for states where around 70% of the production is concentrated in one state, as is the case of sugar cane in Sao Paulo.

Another interesting aspect is that most of the main producers and supermain producers are situated in the Southeast and South regions, another reflection of the uneveness of economic activity in the country.

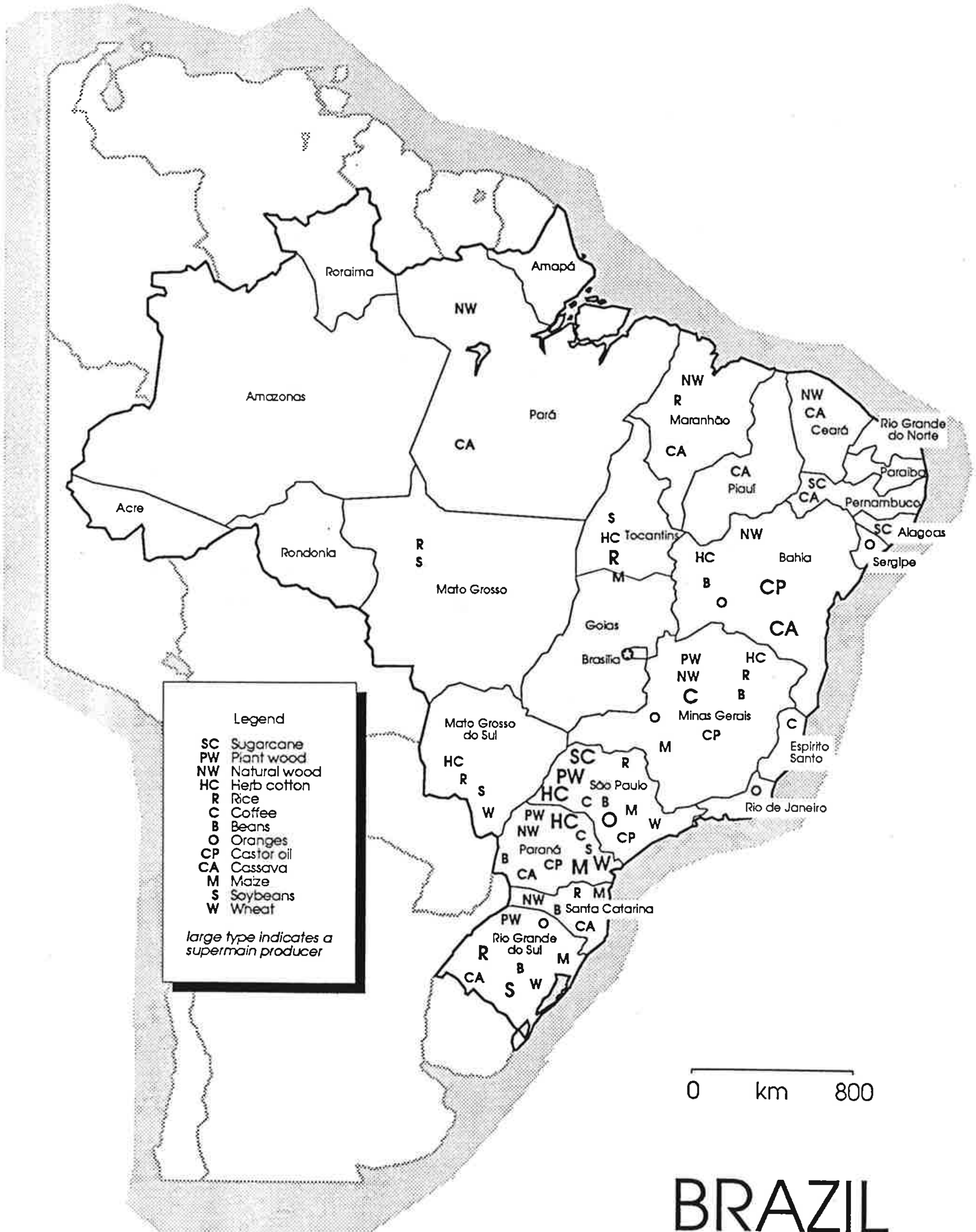
Finally, we note that for some particular crops the Center West region is beginning to appear as an important producer, reflecting the expansion of agricultural frontiers over the last years. The map of Fig. 3.1 reveals the geographical distribution of the main producers and supermain producers for the various crops. The following sections will analyze the possibilities for sugar cane, planted wood and vegetable oil to make major contributions to future energy supply in Brazil.

The reasons to choose these three areas are related to the role they already play in the country's economy, past experience, existing infrastructure and foreseen energy needs that could be covered by them.

The analyses will be based on the general biomass flow shown in Fig. 3.2, comprising the most important phases of its productive cycle. The idea is not to make a descriptive evaluation of each phase, but to bring out the most important parameters related to their use, based on the most reliable information presently available.

Fig. 3.3 details the basic physical flow upon which the analysis will be made. Using the same flow, and starting from the results of the physical analysis, we will attempt to incorporate the social, environmental and economical aspects. This is intended to provide a broad understanding of each studied biomass productive cycle.

Figure 3.1: Main and supermain producers, geographical distribution



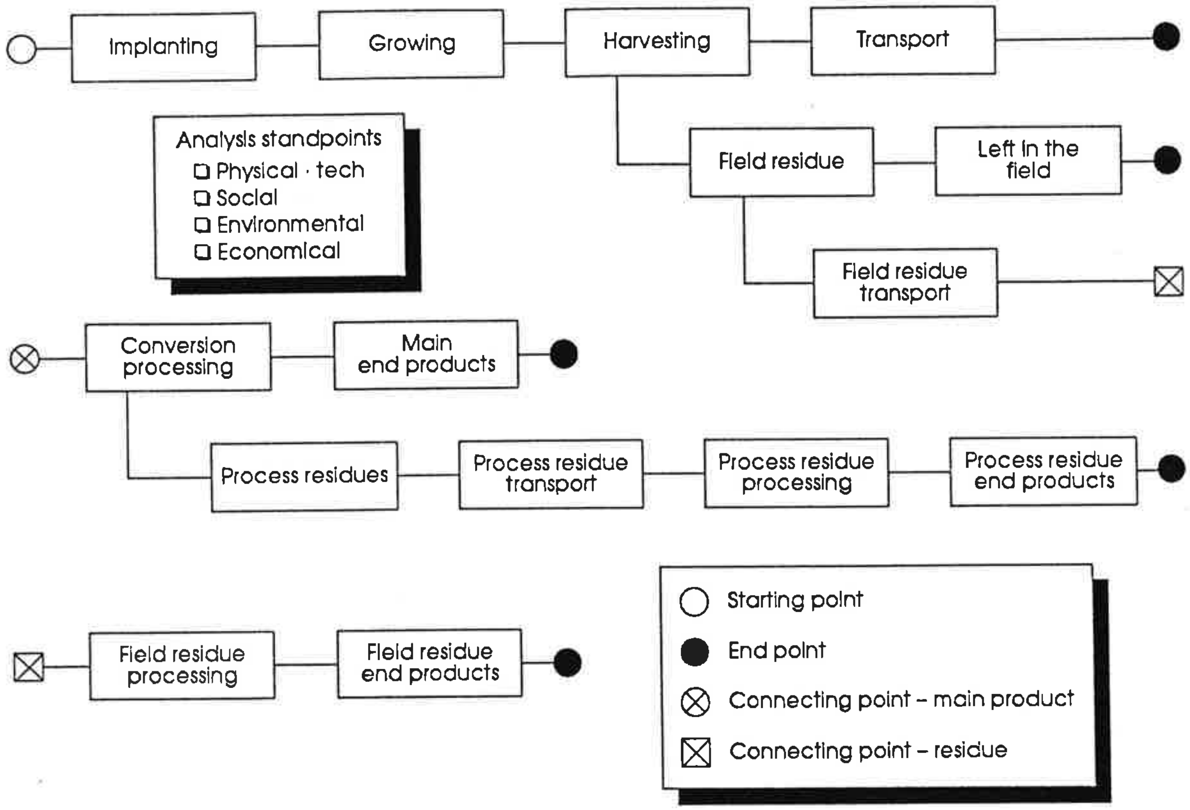


Fig 3.2 : Biomass general flow and analysis structure

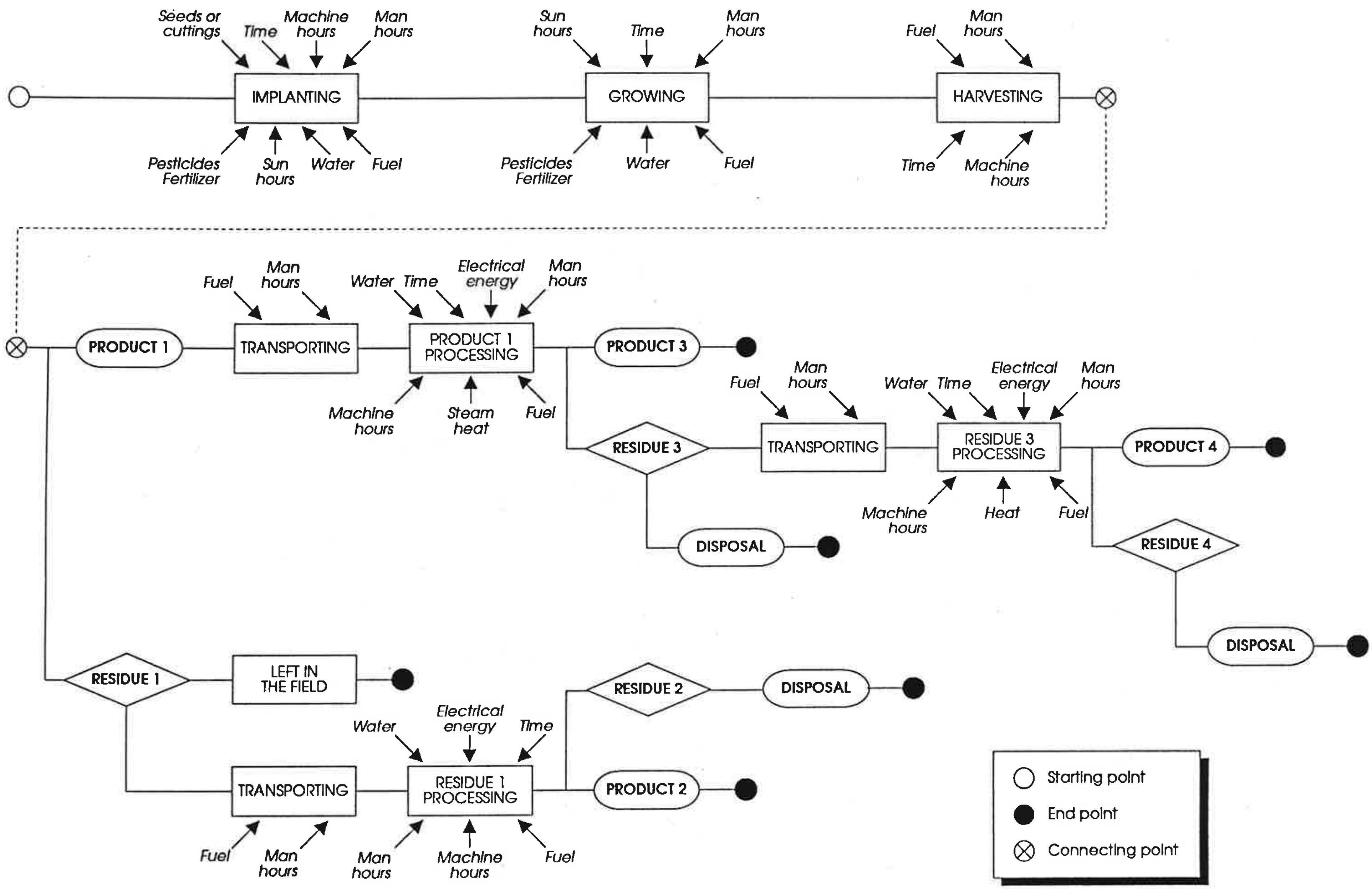


Fig 3.3: Biomass physical flow

As a complement we will discuss probable foreseen improvements in the time frame of the next 10 - 20 years and evaluate their impacts on the whole process.

The following sections contain the basic information gathered for sugar cane, wood and palm oil plantations. The data are put together by relevant aspect and contemplate the physical environment, social, economic and energetic (energy balance) aspects. In each section the explanations relevant to understanding and future use of the data are made, together with comments on the achieved results.

Finally it is important to have in mind that, although a great effort was made to equalize the data for all three agroindustries under analyses, some differences remain, as the stages of development are different among them, as is the available information.

3.2 GENERAL COMMENTS ABOUT THE DATA PRESENTED IN THE FOLLOWING SECTIONS

The basic idea of the following sections is to show the most important parameters related to the productive cycle of sugar cane, wood plantations and palm oil plantations from the aforementioned standpoints. The focus is not on specific cases or maximum efficiencies, but average values of the most relevant parameters, representing the productive cycle of the three biomasses of interest. Fig. 3.4 shows the phases in which the biomass productive cycle is brokendown and the aspects under which each phase was analysed. Each specific section is arranged as follows:

a) A figure showing the physical flow, used as the basic pattern to present the technical parameters. This figure also shows the main parametric aspects of interest related to each phase of the biomass productive cycle.

b) A series of tables containing the data and structured by aspect of interest and, for each aspect, by phase of the productive cycle, which may comprise one table per phase, or one table for all phases.

c) An apendix explains the assumptions made, parameter estimations, basic data for various sources, or for the source available, and in some cases the summary of data from various sources.

d) No comments or analysis is presented with the tables or in the appendix.

It is important to stress that the aim of this section is to provide the basic information for the following chapters and also to supply basic information for further studies. The maximum effort was made to get the most reliable data available and the most representative actual situation of the biomass productive cycles of interest. Finally, although knowing that many further improvements will be possible, as more accurate and reliable information are made available, it is our hope that the aim of the moment will be fulfilled.

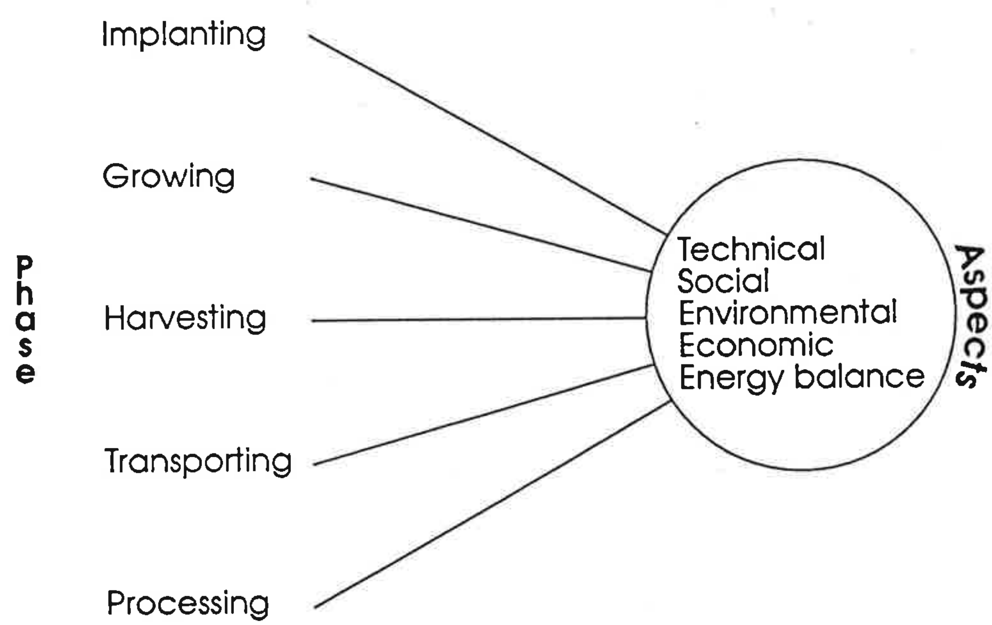


Fig 3.4: Biomass productive cycle

3.3 SUGAR CANE PRODUCTIVE CYCLE

The parameters related to the sugarcane productive cycle are shown in Fig. 3.5 and 34 tables (Tables 3.4 to 3.37) divided as follows:

Aspect	Number of tables
Technical	18
Social	02
Environmental	01
Economic	10
Energy Balance	03

The data are grouped by phase and following the physical flow shown in Fig. 3.5. For the processing phase, as more than one conversion process may be applied, the data are grouped by process, e.g. sugar factory or autonomous distillery.

Social aspects were analysed with a focus on jobs. These data are summarized in two tables, which show the number of employed persons per ha on an annual and seasonal basis. The results emphasize the effects of seasonality of the job opportunities offered by the sugarcane agroindustry during and off the season. The environmental aspects are summarized in one table, the aim of which aim is to stress the main environmental impacts. Any quantification should be made using the technical parameters. The economic data are also shown for each phase of the physical flow and are presented in 10 tables.

The three last tables contain energy balance data. The energy balance for a specific situation is not shown, but in the last table the average output for the most probable situations occurring in the sugar cane industry can be found. Finally, it is recalled that the analysis was made for three time horizons, present, near future (7 to 10 years) and far future (15 to 20 years). The appendix contains most of the assumptions and calculations made to achieve the data presented in the tables.

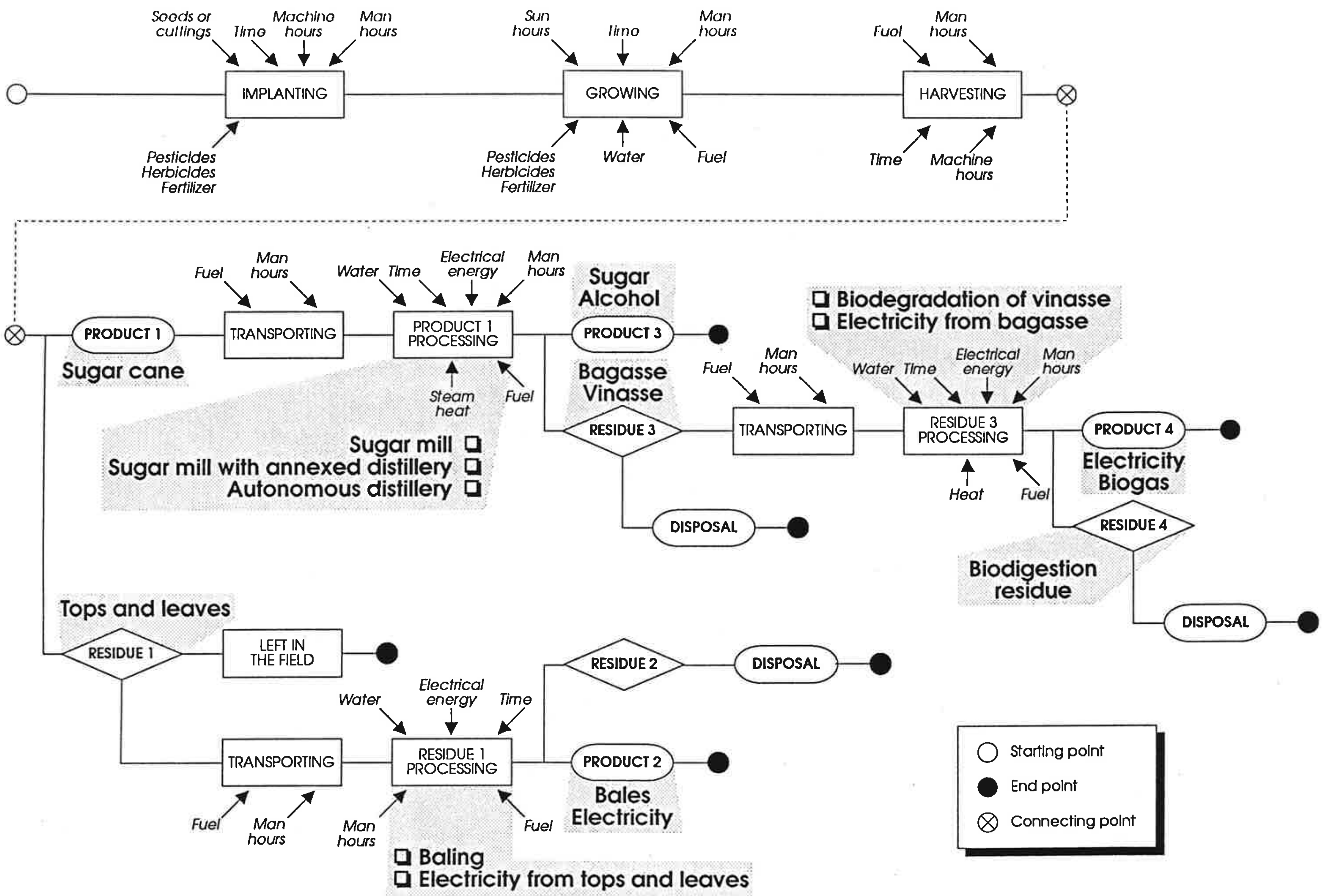


Fig 3.5: Biomass physical flow · Sugar cane

3.4 WOOD PLANTATIONS PRODUCTIVE CYCLE

The parameters related to wood plantations are shown in Fig. 3-6 and 29 tables(Tables 3.38 to 3.66), which are divided as follows:

Aspect	Number of tables
Technical	10
Social	03
Environmental	01
Economic	13
Energy Balance	02

The same approach used to analyse the sugar cane productive cycle was applied for the study of wood plantations. The differences are that wood is not a seasonal crop and only the present situation is addressed. In other words no estimation of possible future gains in productivity were made. The reasoning for choosing this approach was that the use of plantations for energy is relatively new when compared with sugar cane and, for electric energy on a competitive basis, is something yet to come. This is reflected by the quantity and quality of the data available, some of which are results of trials or studies. This fact has lead to the present effort,with the best information at our disposal to get a clear understanding of the actual present situation and explore its possbilities for energy use.

In the chapter dedicated to scenarios it is intended to show extrapolations for some of the data presented in this chapter.

Finally, it is important to mention that although various spacings for trees are in use and different productive cycles are being tried, in this study all the parameters are referred to 3m x 2m spacing, 3 cuts, 6 years between cuts, 18 years per cycle and 2024 productive hours per year.

The appendix contains most of the assumptions, calculations, and the basic information use to construct the tables.

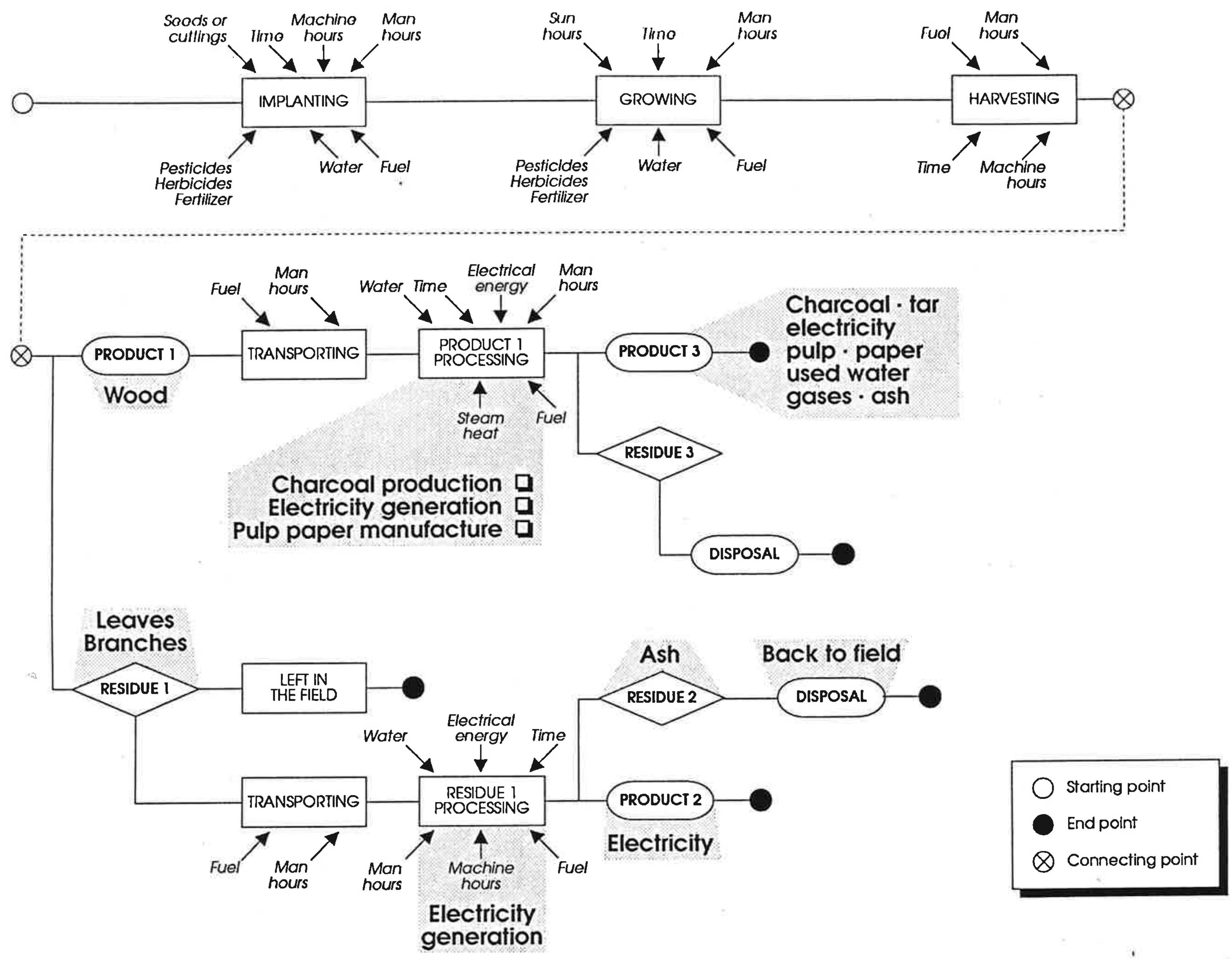


Fig 3.6: Biomass physical flow · Wood plantations

3.5 VEGETABLE OIL PRODUCTIVE CYCLE PALM OIL TREE

As in the previous sections dedicated to sugar cane and wood plantations, the parameters related to palm oil tree (vegetable oil) are presented in tables following the same patterns.

The significant difference is that as the palm oil, is a relatively new modern agroindustry in Brazil, only a small quantity of information is available, which is reflected in the analyses by the number of tables, (Tables 3.67 to 3.76) the blanks in the tables and on the impossibility of showing the energy balance.

The tables are divided as follows:

Aspects	Number tables
Technical	06
Social	01
Environmental	01
Economic	02
Energy Balance	-

Fig. 3.7 shows the physical flow for the palm oil agroindustry and in Appendix A.3.3 are summarized the basic information used to estimate the parameters shown in the tables.

As in the previous cases no evaluation of the results is made here. A comparative analyses is given in chapter 5.

3.6 THE POSSIBLITY OF VEGETABLE OIL AND OR ALCOHOL SUBSTITUE FOR DIESEL

The aim of this secton is to discuss the issue of diesel substitution, showing the past experience, the present situation, a summary of the technical parameters, the potential for substitution and some idea of the costs trade-offs.

These subjects are split in three sub-sections with the first containing the past experience and present situation, the second dedicated to the technical aspects and the third approaching the potential and cost items.

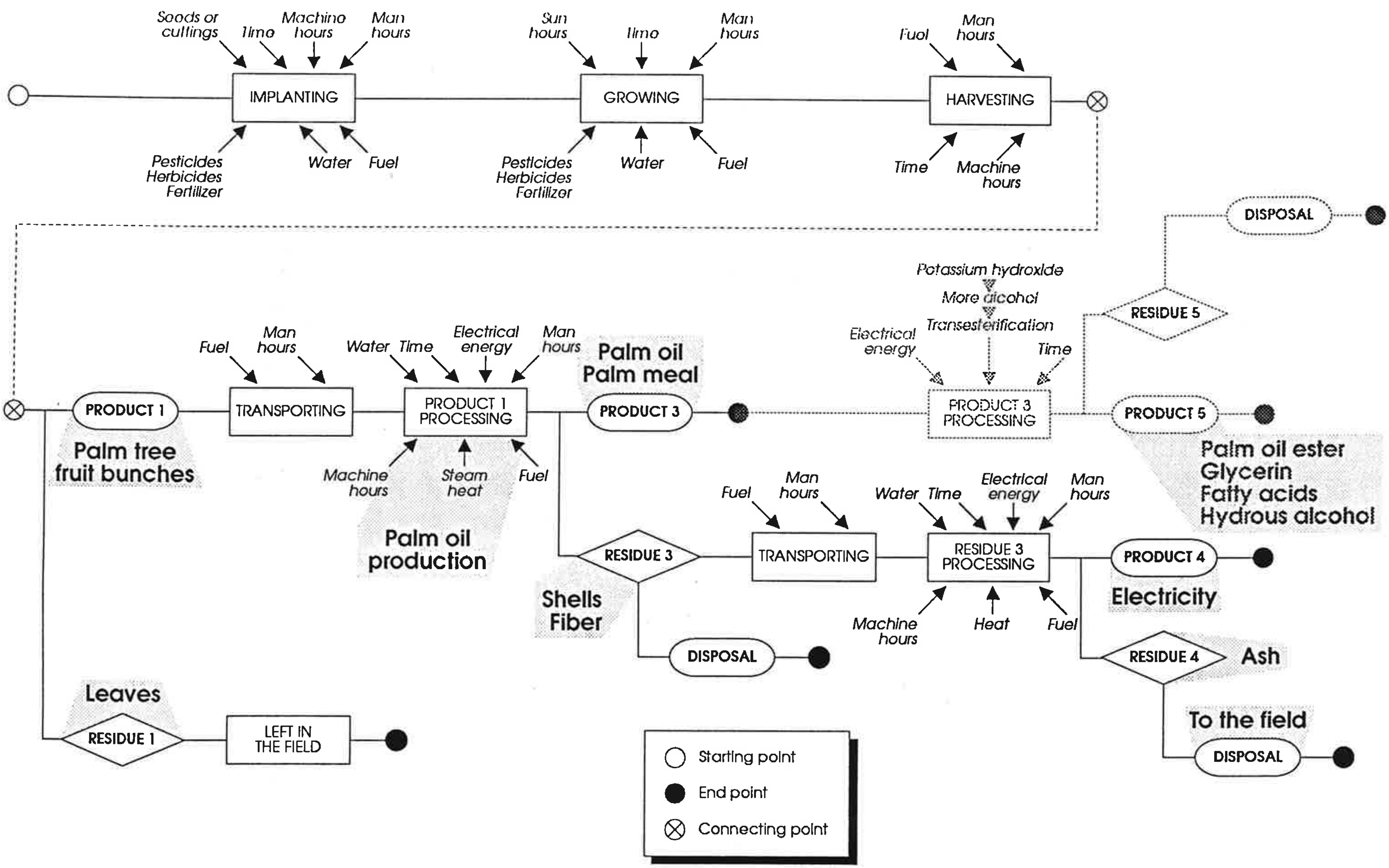


Fig 3.7: Biomass physical flow · Vegetable oil productive cycle
Palm oil tree

3.6.1 SUMMARY OF THE PAST EXPERIENCE AND PRESENT SITUATION REGARDING THE ISSUE OF DIESEL SUBSTITUTION IN BRAZIL

The oil crisis which led to the creation of Brazil's Alcohol National Program and its success in substituting alcohol for gasoline, made diesel oil the main parameter defining the amount of petroleum to be imported by the country. Thus there arose an interest in finding a substitute for it.

As early as 1976 this question has been the object of studies in universities and technological research institutes, various development programs, in most if not all diesel motor manufacturers, conferences, and even of a federal governmental program parallel to the Alcohol Program.

This is not a new issue at all even in international terms, reports dated from 1900 quote Rudolf A. Diesel as mentioning the possibility of using vegetable oil as a fuel for its motors which was demonstrated in a small diesel engine made by the OTTO society in the Universal Exposition in Paris (39). In the 1920's various Rustom diesel motors were fueled with palm oil in the Belgium Congo (today's Zaire) with no problems other than an increase in consumption of 29%. In the 1940's France and India tested and used vegetable oil to fuel diesel motors successfully.

The issue was thoroughly analysed. In 1980 in Sao Paulo at a symposium on vegetable oil as a substitute for diesel, First Symposium on Vegetable Oil Technology (I Econtro Sobre Tecnologia de Oleos Vegetais), attended by representatives of manufacturers, financial institutions, universities, research institutions and governmental agencies. At that time a National Vegetable Oil Program was imminent. Between 1980 and 1983 the catalytic cracking of vegetable oils was studied, and its process developed by the University of Ceara, the Research and Development Center of Bahia, the Military Engineering Institute and by Petrobras (45). During this period the mixture of anhydrous alcohol, up to 3.5%, with diesel was tested. The double injection system reached commercialization phase and the use of alcohol with additive was fully developed as a fuel for diesel motors (45). Also in this period, methylesters and ethylesters were tested as fuels for diesel motors with great success (45).

In 1983 Petrobras successfully tested on an industrial scale the possibilities of mixing up to 10% of vegetable oil within the normal load of its catalytic cracking plants.

Finally, laboratory test reports from the Petrobras Research Center, the Technology Research Institute of Sao Paulo and the Aerospace Technical Center have shown that it is possible to mix up to 30% vegetable oil in diesel, without harm to the motor performance.

In 1985 new studies were made by the group led by Professor Osvalob B. Carioca, at the Federal University of Ceara assessing the prospects for using vegetable oils for energy purposes. More recently the government of Bahia sponsored a study, aiming at the development of palm oil tree plantations in the south east of the state, which concluded the viability of agro industrial projects based on palm oil tree plantations and recommended their implementation.

The conclusion that can be drawn from the aforementioned is that from the technical standpoint the country has mastered the basic knowledge necessay to start a diesel substitution program in the short run, 3 to 5 years. Presently no new progress has been reported in this area, and the impression is that this issue has not even been under consideration over the last few years. Perhaps the Middle East Persian Gulf crisis will lead to modifications in the present stand-still situation. For the moment, there are no hints at all that the use of vegetable oils for energy is under consideration.

3.6.2 TECHNICAL PARAMETERS

Technically, vegetable oils or alcohol can be substituted for diesel oil, in diesel motors. Thus, opportunity and the amount of substitution, if it is going to occur in the future, will be dictated by political, economic and practical reasons and not by technical ones. Having said that, it is interesting to have an idea of the substitution possibilities and the alternatives. Table 3-77 is a summary of the most studied options for diesel replacement. Table 3-78 shows a comparison of physical chemical properties between diesel, vegetable oils and ester from vegetable oils. Table 3-79 is a summary of the available data on fuel consumption derived from tests made by the most important Brazilian motor manufactureres as of 1980. More detailed information is presented in Appendix A 3-4.

The analysis of the data in Table 3-79 shows that there is a difference in the specific consumption between large (buses, trucks and tractors) and small motors (cars and small trucks). The first (large motors) show an increase in consumption when operating with vegetable oil as compared with diesel, while for the small motors there is a decrease. Although this is only an indication from early experiments, it gives a hint of what may be expected, if vegetable oil is chosen to replace part of the diesel oil consumed in Brazil.

3.6.3 DIESEL SUBSTITUTION POSSIBILITIES, POTENTIAL AND COSTS - A PRELIMINARY APPROACH

Brazil has a surplus of gasoline, which results from the amount of petroleum refined being dictated by the diesel consumption. This extra gasoline, poses a difficult fuel handling management problem. Getting rid of this problem is the main driving force to replace part of the present diesel consumption.

In 1980 the transport fleet in Brazil amounted to about 12 million vehicles, of which around 1.3 million used diesel as fuel. In 1985 the corresponding figures were 13 million and 1.7 million, respectively. Although these are not very precise numbers, they give an idea of the size and importance of the diesel substituion issue. They also show that although the fleet as a whole has been increasing around 1.6% a year, the vehicles moved by diesel had an average increase rate of 5.5% per year. Assuming that these rates have remained constant, in 1988 the total fleet would amount to 13.6 million and the diesel vehicles, to about 2.0 million.

As can be seen in Table 3-80, between 1985 and 1988 diesel consumption varied from 20.14 million m^3 to 24.03 million m^3, at an average rate of increase of 6.1% a year, in spite of the sharp decrease in growth rate between 1987 and 1988.

If, beyond the aforementioned, the unsuccessful experience in transforming car motors from gasoline to alcohol that occurred during the early stages of the National Alcohol Program is considered, the natural conclusion is that any diesel substitution program should, or may even be said must have as one of its basic premises the fact that no changes on the existing diesel motors will occur. Accepting this fact, it will be necessary to decide the desired amount of diesel replacement in a certain period of time. This will permit envisaging if it will be sufficient to just substitute in new vehicles, or if it will be necessary to replace a certain amount of the diesel presently used. Assuming that the second premise prevails, which means that an objective would be a significant amount of diesel replacement over a relatively short period of time, the main possibilities of substitution would be as follows:

a) using anhydrous alcohol mixed with diesel up to 3.5%
b) using mixtures of diesel vegetable oil, with up to 20% to 30% of vegetable oil content
c) catalytic cracking of vegetable oil by mixing it in the gasoil stream at the existing petroleum refineries
d) using hydrous alcohol with additives

Alternative (a) has a drawback the fact that only limited substitution could be achieved, requiring a return to the use of tetraethyl lead as a gasoline enhancer, as all the anhydrous alcohol produced in Brazil is used with this purpose. The alternatives (b) and (c) seem to be the most probable to be used to start any diesel replacement program, even though the use of the existing refineries to produce diesel from vegetable oil through catalytic cracking would permit substituting just small amounts (less than 5%) of the diesel consumption. The reason is the fact that the maximum concentration of vegetable oil in the gasoil is 10%, the conversion efficiency is around 53% and not all the diesel is produced through catalytic cracking. All this considered it appears that only about 3% of the total diesel consumption could be replaced by this process. Alternative (d) has as its main drawback the cost of replacement.

Although no actual prices are available, information indicates that the additives are very expensive. On the other hand, the adoption of this alternative would have two parallel effects that combined could bring the expected results. First, it would use part of the alcohol that presently is being used to substitute for gasoline, which means an increase of gasoline demand. Second it would displace a certain amount of diesel, with the same effect. If a diesel substitution is seriously considered, it seems worth analysing this option in detail, mainly its economic aspects, which are its main drawbacks and which may limit its implementation. An analysis of the alcohol-with-additives alternative follows. Table 3-81 shows the data for 100%, 30% and 10%, three arbitrarily chosen substitution possibilities, and the numbers clearly indicate that optimistically 10% is probably the uppermost replacement achievable using alcohol with additives.

As an exercise let's assume that 10% of the diesel is replaced by this process and no new sugar cane plantations or distillery projects are developed.

This means that 3.85 million m^3 of alcohol must be replaced by gasoline. Assuming a volumetric gasoline to alcohol substitution ratio of 1.45, the increase in gasoline consumption would be of the order of 2.66 million m^3, or 28.6% of the 1988 consumption.

Table 3-82 shows the Petrobas forecast of its refinery profile for the period 1980-1989. (45;1)

Assuming the above figures are correct the 2.4 million m^3 of diesel replaced would mean 6.67 million m^3 less petroleum refined and a decrease of 1.13 million m^3 in gasoline production, or around 22% of the gasoline consumption in 1988.

Table 3-83 shows the results of replacing 10% of diesel with alcohol with additives. It indicates that to balance production and consumption, the diesel replacement should be of the order of 8%.

Table 3-84 shows the results of diesel replacement with vegetable oil from palm oil. In this case, since an increase in gasoline consumption does not occur, the rate of substitution could be higher, around 25% to 30%. From the data of Table 3-84, 30% substitution would require less than one million ha of palm oil plantations, which could be achieved in practical terms. The state of Bahia alone has around one million ha in its far Southeast region suitable for use as palm oil plantations (43). Although many other factors must be considered to launch a diesel substitution program, the above information gives an idea of how it could be started, its consequences, and the order of replacement that could be attained.

Table 3.85 contains the prices, costs, densities and heating values for palm oil, alcohol and diesel. The differences among the prices and costs are so significant that it is difficult to see alcohol or palm oil displacing diesel. Table 3.86 shows the prices and costs of the energy contained in each fuel. From these two tables some conclusions can be drawn:

a) Up to the saturation point of the global palm oil market, it would be more interesting to sell it in the international market, get the hard currency and import diesel. Assuming the average values for palm oil costs in Brazil, its price in the international market and the diesel price, each ton of palm oil sold, would buy 0.793t of diesel. It would be an indirect diesel replacement as it would permit a decrease in the amount of crude petroleum imported by buying diesel directly.

b) With saturation of the international palm oil market, a decrease in price would probably occur. The level of decrease and the hidden costs for the Brazilian economy to get the hard currency necessary to buy the diesel would dictate what policy to follow. By hidden costs it is meant the costs of diverting resources from other applications that would provide a future revenue. These aplications may be diverse, such as education, health, infrastructure and so on.

c) Launching a substitution program is a long-term decision, so it would be very important to try to evaluate, with the greatest possible accuracy, the long-term consequences of the program under various scenarios.

d) It is important to always keep in mind the Alcohol program experience, which shows among other things that the high inertia inherent in this kind of project makes it very difficult to make future changes in course.

Finally Table 3.87 shows some additional data related to indirect diesel substitution with palm oil. The area, investment, jobs and the minimum period to get started with effective diesel replacement are important information to have in understanding the size of operations involved in a diesel substitution program.

3.7 Tables

TABLE 3.1 BASIC INFORMATION ON BRAZIL MAIN CROPS - 1987

Crop	Area 1000 ha	Produc. 1000t	t/ha.cut	Product. Value Million US$	US$/ha	Residue
Sugar Cane	4314.1	268741.1	62.3	2788.7	646.4	Bagasse, Tops and leaves (barbojo)
Planted Wood	5049.3	59077.2	11.7	1549.6	306.9	Brances and Leaves (Includes wood for charcoal)
Natural Wood	10721.9	64331.3	6.0	2021.9	188.6	None (Includes wood for charcoal)
Herbaceous Cottons	1277.3	1613.1	1.26	341.7	267.5	Cotton Stalks
Rice	5979.8	10419.0	1.74	1141.5	190.9	Husks and Straws
Coffee	2875.6	4405.4	1.53	2240.1	779.0	Husks and Pulp
Bean	5201.8	2007.2	0.39	643.1	123.6	None
Orange	725.6	73568.8	101.4	1012.2	1395.0	Pulp and Peels
Castor Oil Plant	262.5	103.6	0.39	22.0	83.8	None
Cassava	1936.0	23464.5	12.12	1196.7	618.1	Stems
Maize	13503.4	26802.8	1.98	1697.8	125.7	Stalks and Cob
Soybean	9134.3	16968.8	1.86	1868.1	204.5	Stalks
Wheat	3455.9	6034.6	1.75	1353.5	391.6	Husks and Straw

Source: IBGE Anuario Estatistico do Brasil - 1989

TABLE 3-1

BASIC CONVERSION FACTORS

PRODUCTION	
PLANTED WOOD	30 ST m^3/HA.Y
NATURAL WOOD	20 ST m^3/HA.Y
WEIGTH PER ST m^3	
PLANTED WOOD	0.39 t/ST m^3
NATURAL WOOD	0.30 t/ST m^3

1987 AVERAGE DOLLAR EXCHANGE RATE US$ 1.00 = CZ $ 44.12

d ST m^3 = 1m x 1m x 1m FILLED WITH WOOD

TABLE 3-2 BRAZIL MAINCROP RESIDUES
PRODUCTION AND POSSIBLE APPLICATIONS FOR ENERGY (1988)

	REDIDUE PRODUCTION 1000t	ENERGY CONTENT TJ (LHV)	POSSIBLE END USES	APPLICABLE CONVERSION TECHNOLOGY FOR ENERGY USE	PRESENT LEVEL OF USE 1. LOW OR NONE 2.MEDIUM 3.HIGH
SUGAR CANE B T/L	77568.0 67185.3	651571.2 564356.3	HEAT; ELECTRICITY	H-COMBUSTION; E- (P) STEAM CYCLE (F) GASIF. GAS TURBINE	3 B 1 T/L
PLANTED WOOD	8861.6	74437.4	CHARCOAL; HEAT; ELECTRICITY	C-PYROLYSIS; H-COMBUSTION; E-(P) STEAM CYCLE (F) GASIF. GAS TURBINE	1
NATURAL WOOD	-----	-----	-----		
HERBACEOUS COTTON	8422.4	70748.2	HEAT	H. COMBUSTION	1
RICE	24795.1	208278.8	HEAT; ELECTRICITY	H-COMBUSTION; E-STEAM CYCLE	2
COFFEE					
BEAN	-----	-----	-----		
ORANGE	34577.3	290449.6	HEAT	H-COMBUSTION; PELLETTING	3
CASTOR OIL PLANT	-----	-----	-----		
CASSAVA	3240.5	27220.2	HEAT	H-COMBUSTION	1
MAIZE (CORN)	51871.9	435724.0	HEAT; ELECTRICTY	H-COMBUSTION; BRIQUETTING PELLETTING; E-STEAM CYCLE	1
SOY BEAN	10107.7	849047.7	HEAT	H-COMBUSTION; BRIQUETTING PELLETTING	1
WHEAT	6659.4	55938.7	HEAT	H-COMBUSTION	1

OBS: CONSIDERED AN AVERAGE LHV OF 8.4 GJ/t FOR ALL CROPS RESIDUES. MOISTURE: 40-50%
H - Heat E - Electricity C - Charcoal P - Present F - Future

TABLE 3.2 RESIDUES CONVERSION FACTORS

Crop	Residue	t of Resid. / t of Crop	Adopted t_R/t_c	Source
Sugar Cane	Bagasse	0.3	0.3	Chesf
	Tops & Leaves	0.46 to 0.66 (1) 0.25 (2)	0.25	(1) CEES Eric Larson total Material (2) Top and Attached Leaves Alex Galexander
Planted Wood		0.15	0.15	Peter Olovnilsson
Cotton		3.5	3.5	*Agricultural Residues as Fuel in Third world countries - G. Barnard; L. Kristoferson
Rice	Hull or husks	0.32		*
	Straw	0.83 to 3.3	2.1•	* •Total Rice Resid.
	Total Resid. (Aver. developing countries)	1.75		*
Coffee				
Orange		0.4 to 0.54	0.47	Author Trials
Cassaya	Stem	0.15	0.15	°Biomass Fundam. e Aplicacoes Tecnologicas - J.O.B. Carica - H.L. Arora
Maize	Stalk	1.0 to 2.5		*
	Cob	0.2 to 0.5	2.1•	* •Total Maize Resid.
Soy Bean		0.56	0.56	°
Wheat		0.7 to 1.7	1.2	*

Table 3.3 Brazil Main Crops Geographical Distribution - 1987

	Sugar Cane	Planted Wood	Natural Wood	Herbaceous Cotton	Rice	Coffee	Bean	Orange	Castor Plant	Cassava	Maize (corn)	Soybean	Wheat
<u>North</u>													
Rondonia	x	x	x	x	x	x	x		x	x	x		
Acre	x		x		x	x	x	x		x	x		
Amazonas	x	x	x		x	x	x	x		x	x		
Roraima	x		x		x		x	x		x	x		
Para	x	x	MP	x	x	x	x	x		MP	x		
Amapa	x	x	x		x		x	x		x			
<u>Northeast</u>													
Maranhao	x		MP	x	MP	x	x	x		MP	x	x	
Piaui	x		x	x	x	x	x	x	x	MP	x		
Ceara	x	x	MP	x	x	x	x	x	x	MP	x		
Rio Grande do Norte	x	x	x	x	x	x	x	x	x	x	x		
Paraiba	x		x	x	x	x	x	x	x	x	x		
Pernambuco	MP	x	x	x	x	x	x	x	x	MP	x		
Alagoas	MP		x	x	x	x	x	x	x	x	x	x	
Sergipe	x	x	x	x	x		x	MP		x	x	x	x
Bahia	x	x	MP	MP	x	x	MP	MP	SP	SP	x	x	x
<u>Southeast</u>													
Minas Gerais	x	MP	MP	MP	MP	SP	MP	MP	x	x	MP	x	x
Espirito Santo	x	x	x		x	MP	x	x		x	x		
Rio de Janeiro	x	x	x		x	x	x		MP		x	x	
Sao Paulo	SP	SP	x	SP	MP	MP	MP	SP	MP	x	MP	x	MP
<u>South</u>													
Parana	x	MP	MP	SP	x	MP	MP	x	MP	MP	SP	MP	SP
Santa Catarina	x	x	MP		MP	x	MP	x		MP	MP	x	x
Rio Grande do Sul	x	MP	x		SP		MP	MP		MP	MP	SP	MP
<u>Centerwest</u>													
Mato Grosso do Sul	x	x	x	MP	MP	x	x	x	x	x	x	MP	MP
Mato Grosso	x		x	x	MP	x	x	x	x	x	x	MP	x
Goias	x	x	x	MP	SP	x	x	x		x	MP	MP	x
Distrito Federal	x	x			x	x	x	x		x	x	x	x

MP - Main Producer
x - Producer

SP - Supermain Producer
Source - IBGE Anuario Estatistico do Brazil 1989

TABLE 3-4 SUGAR CANE PRODUCTIVE CYCLE - TECHNICAL ASPECTS

Implanatation Phase		Present	Near Future 7/10 years	Far Future 15/20 years
Expected Product. t_c/ha.cut		65	73	95
Man hours	Mh/ha	94	80	72
Machine hours	Eh/ha	79	83	86
Fuel (diesel)	Kg/ha	248	248	248
Plants	units/ha	8060	8060	8060
Fertilizer N_{16} P_8K_{24}	Kg/ha	620	385	385
Amonium Sulfate		210	130	130
Lime		1670	1670	1670
Pesticides	Kg/ha	0.5	0.5	0.5
Herbicides	Kg/ha	3.3	3.3	3.3

Basic data for present situation Ref. (11).
Near future and far future author assumptions.

TABLE 3-5 SUGAR CANE PRODUCTIVE CYCLE - TECHNICAL ASPECTS

Growing Phase		Present	Near Future 7/10 years	Far Future 15/20 years
Expected Productivity t_c/ha.cut		65	73	95
Total Growing period	Mo.	60	48	48
Growing between cuts	Mo.	15	16	16
Cuts between implantations		4	3	3
Green Productivity for the total growing period	t_c/ha	260	219	285
Productivity between cuts	t_c/ha.cut	65	73	95
Yearly productivity	t_c/ha.y	52	54.8	71.3
Man hours	Mh/ha	367.8	283.8	295.5
Machine hours	Eh/ha	97	59	54
Fuel (diesel)	kg/ha	299.2	182	134
Fertilizer ($N_{16}P_8K_{24}$	kg/ha	1230	508.4	508.4
Pesticide	kg/ha	1.5	1.0	1.0
Herbicide	kg/ha	9.9	6.6	6.6
Sun hours for the growing period	h	12500	10000	10000
Sun hours per year	h/y	2500	2500	2500
Sun energy for the growing period	TJ/ha	343.8	274.9	274.9
Sun energy per year	TJ/ha.y	68.8	68.8	68.8
Sun energy per tc	TJ/tc	1.32	1.26	0.96
Used water per tc	m^3/t_c	100	91	86
Used water per ha per cut	m^3/ha.cut	6500	6643	8213
Used water per ha.y	m^3/ha.y	5200	4987	6132
Available water per ha per year	m^3/ha.y	14000	14000	14000

TABLE 3-6 SUGAR CANE PRODUCTIVE CYCLE - TECHNICAL ASPECTS

Harvesting Phase

		Present	Near Future 7/10 yrs.	Far Future 15/20 yrs.
Expected Productivity t/ha.cut		65	73	95
Man hours	Mh/ha	491.6	397.7	207
Machine hours	Eh/ha	34.4	22.8	17
Fuel (diesel)	kg/ha	79.1	66	49.4
Number of cuts between implantations		4	3	3
Green productivity for the total growing period	t_c/ha	260	219	285
Productivity between cuts	t_c/ha.cut	65	73	95
Yearly productivity	t_c/ha.y	52	54.8	71.3
Harvesting Residue (Tops and Leaves)				
Total Residue	t_{tl}/ha	119.8	100.7	131
Residue per cut	t_{tl}/ha/cut	30	33.7	43.7
Residue per year	t_{tl}/ha.y	24	25.2	32.8
Available Reside to Use				
Total Residue	t_{tl}/ha	65	54.8	71.3
Residue per cut	t_{tl}/ha.cut	16.3	18.3	23.8
Residue per year	t_{tl}/ha.y	13	13.7	17.8

TABLE 3-7 SUGAR CANE PRODUCTIVE CYCLE - TECHNICAL ASPECTS

Harvesting Phase

		Present	Near Future 7/10 years	Far Future 10/15 years
Expected Productivity t_c/ha.cut		65	73	95
Man hours per tc	MH/tc	1.9	1.8	0.73
Man hours per cut	MH/cut	123	132.6	69
Machine hours per tc	Eh/tc	0.13	0.10	0.06
tc per Machine hour	tc/Eh	7.7	10	16.7
Machine hours per cut	Eh/cut	8.6	7.6	5.7
Fuel per tc	kg/tc	0.30	0.30	0.18

TABLE 3-8 SUGAR CANE PRODUCTIVE CYCLE - TECHNICAL ASPECTS

Transport

Expected Production	tc/ha.cut	73	95	65
Man hours	MH/ha	91.24	109.5	114.3
Machine hours	Eh/ha	105.4	123.3	129.7
Fuel (diesel)	kg/ha_{tot}	330.8	380.4	407.1
	kg/tc	1.51	1.33	1.57
	kg/cut	110.3	126.8	101.8
Transport. Weight Total	tc/ha	219	285	260
Avererage per cut (Harvesting)	tc/ha	73	95	65
1° Cut	tc/ha	103	134	100
2° Cut	tc/ha	62	81	60
3° Cut	tc/ha	54	70	54
4° Cut	tc/ha	-	-	46
Average per year	tc/ha.y	54.8	71.3	52

TABLE 3-9 SUGAR CANE PRODUCTIVE CYCLE - TECHNICAL ASPECTS

Processing - Present: 65 t_c/ha

Sugar Mill		per t_c	per ha.cut	per ha.y	
Produc. sugar	kg	110	7150	5720	
molasse	kg	29	1885	1508	
Req. Steam	ts	0.45	29.3	23.4	
Electr.	kwh	15.0	975	780	
Wash. water	m^3	3.0	195	156	minimum
Process. water	m^3	1.27	82.6	66	
Men hours	MH	1.127	73.3	58.6	
Fuel	t_f	0.23	15.0	12.0	50% moist. bagasse
Prod. residue 3					
Bagasse	t_b	0.3	19.5	15.6	
Bagasse surplus	t_b	.07	4.6	3.6	
Electr. product	kwh	18	1170.0	936	using all bagasse avail- able
Electr. surplus	kwh	3	195	156	

65 t_c/ha.cut

52 t_c/ha.y

TABLE 3-10 SUGAR CANE PRODUCTIVE CYCLE - TECHNICAL ASPECTS

Processing Present 65 t/ha.
Sugar mill with distillery

Production			per t_c	per ha.cut	per ha.y	
Sugar	A	kg	74	4810	3848	
	B	kg	96	6240	4992	
	C	kg	110	7150	5720	
Alcohol	A	l_a	25	1625	1300	
	B	l_a	13	845	676	
	C	l_a	9.2	598	478.4	
	Cane	l_a	70	4550	3640	
Required Steam		t_s	0.464	30.2	24.1	
Electricity		kwh	18	1170	936	
Wash. water		m^3	3	195	156	min.
Process. Water		m^3	1.27	82.6	66	
Man hours		MH	1.127	73.3	58.6	
Fuel		t_f	0.23	15	12	50% moist. bagasse
Produced Residue (3)						
bagasse		t_b	0.3	19.5	15.6	
bagasse surplus		t_b	0.07	4.6	3.6	
vinasse	A	m^{3v}	.325	21.1	16.9	
	B	m^3_v	.169	11.0	8.8	
	C	m^3_v	.120	7.8	6.2	
	cane	m^{3v}	.910	59.2	47.3	
Electricity Produc.		kwh	18	1170	936	Using all bagasse avail-able
Surplus		kwh	0	0	0	

65 t/ha.cut
52 t/ha.y

TABLE 3-11 SUGAR CANE PRODUCTIVE CYCLE - TECHNICAL ASPECTS

Processing present 65 t/ha.cut
Autonomous distillery

Production		per tc	per ha.cut	per ha.y	
Alcohol	l_a	70	4550	3640	
Required					
Steam	t_s	0.47	306	24.4	
Electricity	kwh	13	845	676	
Wash. water	m^3	3	195	156	Min.
Proces. water	m^3	0.65	42.3	33.8	
Manhours	Mh	1.127	73.3	58.6	
Fuel	T_f	0.235	15.3	12.2	50% Moist. Bagasse
Product residue (3)					
Bagasse					
Product	t_b	0.3	19.5	15.6	
Surplus	t_b	0.065	4.23	3.4	
Vinasse	m^3	0.910	59.2	47.3	
Electricity					
Product.	kwh	18	1170	936	Using all avail-able bagasse
Surplus	kwh	5	325	260	

65 t/ha.cut
52 t/ha.y

TABLE 3-12 SUGAR CANE PRODUCTIVE CYCLE - TECHNICAL ASPECTS

Processing near future 7/10 years 73 T/ha
Sugar mill

Production		per t.	per ha	per ha.y	
Sugar productivity	kg	110	8030	6028	
molasses	kg	29	2117	1589.2	
Required					
Steam	t_s	0.26	19	14.2	
Electricity	kwh	15	1095	822	
wash. water	m^3	3.0	219	164.4	Min.
process water	m_3	1.25	91.3	68.5	
manhours	Mh	1.014	74	55.6	
fuel	t_f	0.13	9.5	7.1	50% moist. bagasse
Residue (3)					
Bagesse	t_B				
Production		0.30	21.9	16.4	
surplus		0.17	12.4	9.3	
Electricity	kwh				
production		100	7300	5480	Using all avail. bagasse
surplus		85	6205	4658	

73 t/ha.cut
54.8 t_c/ha.y

TABLE 3-13 SUGAR CANE PRODUCTIVE CYCLE - TECHNICAL ASPECTS

Processing near future 73 t/ha
Sugar mill with distillery

Production		per t	per ha	per ha.y	
sugar A	kg	74	5402	4055.2	
B	kg	96	7008	5260.8	
C	kg	110	8030	6028	
alcohol A	l_a	25	1825	1370	
B	l_a	13	949	712.4	
C	l_a	9.2	671.6	504.2	
cane	l_a	70	5110	3836	
Required					
Steam	t_s	0.26	19	14.2	
electricity	kwh	15	1095	822	
wash water	m^3	3.0	219	164.4	
process water	m^3	1.25	91.3	68.5	Min.
manhours	Mh	1.014	74	55.6	
fuel	t_f	0.13	9.5	7.1	50% moist. bagasse
Residue (3)					
Bagasse	t_b				
Product		0.30	21.9	16.4	
surplus		0.17	12.4	9.3	
Vinasse	m^3				
A		0.28	20.4	15.3	
B		0.14	10.2	7.7	
C		0.10	7.3	5.5	
cane		0.77	56.2	32.5	
Electricity	kwh				
Production		100	7300	5480	Using all avail. bagasse
surplus		85	6205	4658	

73 t/ha.cut
54.8 t/ha.y

TABLE 3-14 SUGAR CANE PRODUCTIVE CYCLE - TECHNICAL ASPECTS

Processing near future 73 T/ha
Autonomous distillery

Production		per t	per ha	per ha.y	
alcohol	l	70	5110	3886	
Required					
Steam	t_s	0.26	19	14.2	
electricity	kwh	13	949	712.4	
Wash water	m^3	3.0	219	164.4	
process water	m^3	0.57	41.6	31.2	
manhours	Mh	1.014	74	55.6	
fuel	t_f	0.13	9.5	7.1	50% moist. bagasse
Residue (3)					
Bagasse	t_b				
Product		0.30	21.9	16.4	
surplus		0.17	12.4	9.3	
Vinasse	m^3	0.77	56.2	42.2	
Electricity	kwh				
Production		100	7300	5480	Using all avail. bagasse
surplus		87	6351	4767.6	

73 t/ha.cut
54.8 t/ha.y

TABLE 3-15 SUGAR CANE PRODUCTIVE CYCLE - TECHNICAL ASPECTS

Sugar Mill
Processing For future 15/20 years 95 t/ha.cut

Production		per ton	per ha.cut	per ha.y	
Sugar	kg	110	10450.0	7843	
molasses	kg	29	2755	2067.7	
Required					
steam	t_s	.26	24.7	18.5	
electricity	kwh	15	1425	1069.5	
Wash. water	m^3	3.0	285	213.9	Min.
process water	m^3	1.25	118.8	89.1	
manhours	mh	0.86	81.7	61.3	
fuel	t	0.30	28.5	21.4	
Residue (3)					
Bagasse					
Product	t_b	0.30	28.5	21.4	
surplus	t_b	0	0	0	
electricity		225	21375	16093	
surplus	kwh	210	19950	14973	

95 t/ha.cut
71.3 t/ha.y

TABLE 3-16 SUGAR CANE PRODUCTIVE CYCLE - TECHNICAL ASPECTS

Processing far future 15/20 years 95 t/ha
Sugar mill with distillery

Production		per t_c	per ha.cut	per ha.y	
Sugar A	kg	74	7030	5276.2	
B	kg	96	9120	6844.8	
C	kg	110	10450	7843.0	
Alcohol A	l	25	2375	1782.5	
B	l	13	1235	927.0	
C	l	9.2	874	656.0	
cane	l	70	6650	4991.0	
Required					
steam	t_s	0.26	24.7	18.5	
electricity	kwh	15	1425	1069.5	
Wash. water	m^3	3.0	285	213.9	Min.
process water	m^3	1.25	118.8	89.1	
manhours	MH	0.86	81.7	61.3	
fuel	t_c	0.3	28.5	21.4	50% Moist. Bagasse
Residue					
Bagasse	t_b				
Product.		0.3	28.5	21.4	
surplus		0	0	0	
vinasse	m^3				
A		0.28	26.6	20.0	
B		0.14	13.3	10.0	
C		0.10	9.5	7.1	
cane		0.77	73.2	54.9	
electricity	kwh	225	21375	16043	Using all avail. bagasse
production		210	19950	14973	
surplus					

95 t/ha.cut
71/3 t_c/ha.y

TABLE 3-17 SUGAR CANE PRODUCTION CYCLE - TECHNICAL ASPECTS

Processing far future 15/20 years 95 T/ha
Autonomous distillery

Production		per t	per ha.cut	per ha.y	
Alcohol	l	70	6650	4991	
Required					
steam	t	0.26	24.7	18.5	
electricity	kwh	13	1209	926.9	
Wash. water	m^3	3.0	285	213.9	
process water	m^3	0.57	54.2	40.6	
manhours	MH	0.86	81.7	61.3	
fuel	t_f	0.3	28.5	21.4	15% moist
Residue					
Bagasse	t				
product		0.30	28.5	21.4	
surplus		0	0	0	
vinasse	m^3	0.77	73.2	54.9	
electricty	kwh				
product		225	21375	10643	
surplus		212	20140	15116	

95 t/ha.cut
71.3 t/ha.y

TABLE 3-18 SUGAR CANE PRODUCTIVE CYCLE - TECHNICAL ASPECTS

Residue-1 Tops and leaves

Near future - Possible future uses 73 t/ha.cut or 54.8 t/ha.y

		per T	per ha	per ha.y
Material in the field	t_{tL}	0.25	18.25	13.7
Average recovered material	t_{tL}	0.18	13.14	9.9
Baling-production	t_b	0.18	13.14	9.9
Manhours	MH	0.75	54.8	41.1
Machine hours	EH	0.43	31.4	23.6
Fuel	kg	4.0	292	219.2
Baling-transport				
manhours	MH	1.7	124.1	93.2
mach. hours	EH	0.3	21.9	16.4
fuel	kg	0.77	56.2	42.2
Electricity product CEST total	kwh	116	8468	6357
Top/leaves transp. for electricity				
manhours	MH	1.25	91.3	68.5
mach. hours	EH	1.44	105.1	78.9
fuel	kg	1.51	110.2	82.7

73 t_c/ha.cut
54.8 t_c/ha.y

TABLE 3-19 SUGARCANE PRODUCTIVE CYCLE - TECHNICAL ASPECTS

Residue-1 Tops and leaves

Far future Possible future uses 95 t/ha.cut 71.3 t/ha.y

		per tc	per ha.cut	per ha.y
Material in the field	t_{tL}	0.25	23.8	17.8
Average recovered material	t_{tL}	0.23	21.9	16.4
Baling production				
production	t^3	0.27	25.7	19.3
manhours	MH	0.68	64.6	48.5
mach. hours	EH	0.39	37.0	27.8
fuel	kg	0.36	34.2	25.7
Baling transport				
manhours	MH	1.0	95	71.3
mach. hours	EH	0.24	22.8	17.1
fuel	kg	0.69	65.6	49.2
Electricity product BIG/STIG Total	kwh	175	16625	12478
Top leaves transp. for electricity prod.				
manhours	MH	1.13	107.4	80.6
mach. hours	EH	1.30	123.5	92.7
fuel	kg	1.34	127.3	95.5

95 t_c/ha.cut

TABLE 3-20 SUGAR CANE PRODUCTIVE CYCLE - TECHNICAL ASPECTS

Residue 3 Vinasse (stillage)

Near future 73 t_c/ha.cut 54.8 t_c/ha.y

		per t_c	per ha.cut	per ha.y
Production	m^3	0.77	56.2	42.2
Biogas product	nm^3	9.24	674.5	506.4
Biodigested vinasse vinasse	m^3	0.72	52.6	39.5
Biogas heat.value	GJ	0.198	14.5	10.8
Electricity Production	kwh			
Conversion System - CEST		11.6	847	636
GT		18.2	1329	997
STIG		20.4	1489	1118

TABLE 3-21 SUGAR CANE PRODUCTIVE CYCLE - TECHNICAL ASPECTS

Residue 3 Vinasse (stillage)

Far future 95 t_c/ha.cut 71.3 t_c/ha.y

		per t_c	per ha.cut	per ha.y
Production	m^3	0.77	73.2	54.9
Biogas production	nm^3	9.24	877.8	658.8
Biodigested vinasse	m^3	0.72	68.4	51.3
Biogas heat value	GJ	0.198	18.8	14.1
Electricity production	kwh			
Converstion System				
GT		18.2	1729	1298
STIG		20.4	1938	1455

TABLE 3-22 SUGAR CANE PRODUCTIVE CYCLE - SOCIAL ASPECTS

Employments in the sugar cane agroindustry - summary

Seasonal basis - men per ha (M/ha)

Phase	Present (63 t_c/ha)	Near future (73 t_c/ha)	Far future (95 t_c/ha)
Agricultural	0.153	0.153	0.115
Transport	0.018	0.018	0.022
Processing	0.027	0.025	0.028
Subtotal	0.198	0.196	0.165
Residue tops, leaves			
Baling		0.108	0.096
Electricity product		0.014	0.016
Total T;L Baling	0.198	0.304	0.261
T;L Electricity		0.210	0.181

TABLE 3-23 SUGAR CANE PRODUCTIVE CYCLE - SOCIAL ASPECTS

Employment in the sugar can agroindustry - summary

Annual basis - men per ha (M/ha)

Phase	Present ($63\ t_c$/ha)	Near future ($73\ t_c$/ha)	Far future ($95\ t_c$)
Agricultural	0.086	0.086	0.065
Transport	0.010	0.010	0.012
Processing	0.027	0.025	0.028
Subtotal	0.123	0.121	0.105
Residue Tops leaves			
Baling		0.061	0.054
Electricity Product.		0.008	0.009
Total T;L Baling	0.123	0.182	0.159
T;L Electr.		0.129	0.114

TABLE 3-24 SUGAR CANE PRODUCTIVE CYCLE - ENVIRONMENTAL ASPECTS

Areas of concern

Phase	Main causes of impact	Effects on the environment
Implanting	over fertilization over use of pesticides and herbicides soil exposure	leaching of fertilizers, pesticides and herbicides to rivers and other water sources manipulation hazards loss of soil, soil carry over to rivers or water streams
harvesting	burns of green sugar cane use of tractors and trucks or any other heavy equip. soil exposure	air pollution by particulates from uncontrolled combustion soil damage or compactation by heavy equipment during harvesting or tops and leaves collection loss of soil
processing	vinasse (stillage) disposal w/o treatment high BOD/COD poor bagasse combustion for steam or electricity washing waters	water streams pollution caused by improper disposal of vinasse CO air pollution air pollution by particulates emission water streams pollution by improper disposal of washing waters, silting of rivers

TABLE 3-25 SUGAR CANE PRODUCTIVE CYCLE - ECONOMIC ASPECTS

Agricultural and Transport costs - 1988 US dollars

	Present 65 t_c/ha.cut		Near future 73 t_c/ha.cut	
Phase	\$/t_c	\$/ha.cut	\$/t_c	\$/ha.cut
Implanting	3.72	241.80	2.79	203.67
Growing	3.71	241.15	2.78	202.94
Harvesting	1.90	123.50	1.43	104.39
General Exp.	0.97	63.05	0.73	53.29
Social, Tax Exp.	0.14	9.10	0.11	8.03
Adm. Exp.	0.67	43.55	0.50	36.5
Finance Exp.	2.32	150.80	1.74	127.02
Transport	1.47	95.55	1.10	80.30
Total cost	14.90	968.50	11.18	816.14

TABLE 3-26 SUGAR CANE PRODUCTIVE CYCLE - ECONOMIC ASPECTS

Processing operational costs

Annexed distillery 1988

	Present	65 t_c/ha.cut	Near future 73 t_c/ha.cut	
Cost item	\$/t_c	\$/ha.cut	\$/t_c	\$/ha.cut
Processing	1.45	94.25	1.25	91.25
Tax and Insur. Exp.	0.027	1.76	0.02	1.46
Financial Exp.	0.83	53.95	0.71	51.83
Adm. Exp.	0.22	14.30	0.19	13.87
Storage Exp.	0.47	30.55	0.4	29.20
Total processing cost	2.99	194.81	2.57	187.61

TABLE 3-27 SUGAR CANE PRODUCTIVE CYCLE - ECONOMIC ASPECTS

Processing operation costs

Autonomous distillery -$1988 US$

	Present	65 t_c/ha.cut	Near future 73 t_c/ha.cut	
Cost item	$/$t_c$	$/ha.cut	$/$t_c$	$/ha.cut
Processing	2.40	156.00	2.06	150.4
Tax and insurance	0.05	3.25	0.04	2.92
Financial Exp.	2.19	142.35	1.88	137.24
Adm. Exp.	0.32	20.80	0.28	20.44
Storage Exp.	-	-	-	-
Total processing cost	4.96	322.40	4.26	311.00

TABLE 3-28 SUGAR CANE PRODUCTIVE CYCLE - ECONOMIC ASPECTS

Processing operational costs - 1988 US$

Estimated overall processing costs for Brazil

	Present		Near future	
	Alc. Prod.	Proc. cost	Alc. Prod.	Proc. cost
	%	$/tc	%	%/tc
Autonomous distillery	40	4.96	58	4.26
Annexed distillery	60	2.99	42	2.57
Overall cost	100	3.78	100	3.55

	Present	Near future
Overall cost per/ha	$/ha	$/ha
Present 65 t_c/ha.cut	245	
Near future 73 t_c/ha.cut		259.20

TABLE 3-29 SUGAR CANE PRODUCTIVE CYCLE - ECONOMIC ASPECTS

Residue 1 Tops and leaves - Baling 1988 - US$

	Near future (73 t_c/ha.cut)		Far future (95 t_c/ha.cut)	
Item	$/$t_c$	$/ha.cut	$/$t_c$	$/ha.cut
Invest cost	0.66	48.18	0.76	7220
Rent. Equip.	0.71	51.83	0.83	7885
Maintenance	0.92	67.16	1.06	100.70
Fuel	0.17	12.41	0.20	19.00
Labor	0.15	10.95	0.18	17.10
Storage	0.24	17.52	0.28	26.60
Total	2.85	208.05	3.31	314.45
Baling	2.08	151.84	2.42	229.55
Transport of bales	0.77	56.21	0.89	84.90
ELECTRICITY PRODUCTION				
Baling	-	-	-	-
Transp.	1.10	80.3	-	-
Total	1.10	80.3	-	-

Remarks: Electricity production with tops and leaves assuming that they are not baled. In this case was assumed that the transport cost would be the same as for the transport of sugar cane.

TABLE 3-30 SUGAR CANE PRODUCTIVE CYCLE - ECONOMIC ASPECTS

Biodigestion - costs - 1988 US$

Plant size			
Sugar cane crushing capac.	t_c/d	1714	3429
Vinasse (stillage) production	m^3/d	1320	2640
Biogas product	nm^3/d	15837	31675
Investment cost			
Total $		572476.00	1144952.00
	$\$/(t_c/d)$	334.00	334.00
	$\$/(nm^3/d)$	36.15	36.15
Operation/Maintenance Costs			
	Total $/y	30100	30100

TABLE 3-31 SUGAR CANE PRODUCTIVE CYCLE - ECONOMIC ASPECTS

Sugar factory costs 1988 - US$

Plant size			
Crushing capacity			
Daily	t_c/d	1714	3429
Hourly	t_c/d	71.43	142.86
Investment cost			
Total investment	10^3\$	10450	16447
Invest per daily capacity	\$/(t_c/d)	6097	4796
Op./Maintenance costs	Ref (14)		
Fixed costs 10^3\$/y	H	1021	
	L		
Variable costs \$/t_c	H	4.17	
	L		

TABLE 3-32 SUGAR CANE PRODUCTIVE CYCLE - ECONOMIC ASPECTS

Sugar factory with annexed distillery

Costs 1988 US$

Plant size				
Crushing capacity				
Daily	t_c/d	1714		3429
Hourly	t_c/h	71.43		142.86
Alcohol product				
Daily	m^3/d	15		30
Investment cost				
Total investment	$10^3$$	11963		18828
Invest. per daily capacity	$/($t_c$/d)	6980		5491
Op./Maintenenenc cost Ref. (14)		S. Fact.	Dist	Total
Fixed costs $10^3$$/y	H L	1021	181	1202
Variable costs $/$t_c$	H L	4.17	0.038	4.208

TABLE 3-33 SUGAR CANE PRODUCTIVE CYCLE - ECONOMIC ASPECTS

Autonomous distillery 1988 - US$

Plant size			
Daily capacity	m^3/d	120	240
	tc/d	1714	3429
Hourly crushing capacity	tc/d	71.43	143.86
Investment cost			
Total investment	10^3 \$	11721	18447
Invest per daily capacity	\$/(m^3/d)	97675	76862
	\$/(tc/d)	6837.20	5830.30
Op./Maintenence costs Ref. (14)			
Fixed costs 10^3\$/y	H	1108	
	L	1048	
Variable costs \$/tc	H	3.66	
	L	0.18	

TABLE 3-34 SUGAR CANE PRODUCTIVE CYCLE - ECONOMIC ASPECTS

Possible future changes in the cost structure
of the sugar cane industry - 1988 US$

Processing facilities

Invest. Cost $10^3$$

	tc/d	SF	SF+AN.DIST	AUT.DIST
	1714	9248.3	10587.3	10373.1
	3429	14555.6	16662.8	16325.6
Op./Maint.				
Fixed $10^3$$/y		1021	1202	1080
Variable $/Tc	H	4.17	4.21	3.66
	L			0.18

Generating facilities

	Inv $10^3$$	Oper./Maint. Fixed $10^3$$/y	Var. $/kwh
CEST			
1714	14987	343.2	0.003
3429	29973	343.2	0.003
BIG/STIG			
1714	19926	600	0.001
3429	35310	1055	0.001

TABLE 3-35 SUGAR CANE PRODUCTIVE CYCLE - ENERGY BALANCE

Basic data Ref. 16;11;10

ENERGY INPUTS

Agricultural phase	MJ/t_c
Manufac. of agricul. equip.	32.3
Fuel	180.2
N fertilizer	55.4
P	7.1
K	7.7
Lime	2.9
Seeds	15.2
Insecticides	0.2
Herbicides	4.4
TOTAL AGRIC.	305.4
Processing phase	
Manufacture of equip.	51.5
Operation	40.2
Maintenence	51.5
TOTAL PROCESS.	143.2
Residues Tops/leaves fuel	44.0
Sun Energy	$1.0\text{-}1.3*10^6$

TABLE 3-36 SUGAR CANE PRODUCTIVE CYCLE - ENERGY BALANCE

ENERGY OUPUTS		MJ/tc
Alcohol		1489
Bagasse	50% moist	2261
	20% moist	2503
Tops/leaves		
Total	50% moist	3468
	20% moist	3829
Recoverable	50% moist	1885
	20% moist	2084
Biogas		234
Electricity		
Bag.	CEST(1)	313
	BIG/STIG (2)	763
Top/Leaves	CEST (3)	418
	BIG/STIG (4)	630
Biog.	CEST (5)	66
	BIG/STIG (6)	74

TABLE 3-37 SUGAR CANE PRODUCTIVE CYCLE - ENERGY BALANCE

ENERGY OUTPUTS MAIN POSSIBILITIES

	MJ/tc
Al	1489
Al + BAG 50%	3750
Al + BAG 50% + BIOG	3984
AL + BAG 50% + BIOG + TL 50%	7452
Al + BAG 50% + BIOG + RTL 50%	5869
Al + BAG 20%	3992
Al + BAG 20% + BIOG	4226
Al + BAG 20% + BIOG + TL 20%	8055
Al + BAG 20% + BIOG + RTL 20%	7694
Al + ELECT (1)	1802
Al + ELECT (2)	2252
Al + ELECT (1+3)	2220
Al + ELECT (1+3+5)	2286
Al + ELECT (2+4)	2882
Al + ELECT (2+4+6)	2956

TABLE 3-38

Wood Productive Cycle

Technical Aspects

IMPLANTATION PHASE

Plant spacing		3m x 2m	
		3m x 1.5m	
Plants per ha:			
3 x 2		1670	
3 x 1.5		2222	
Manhours: Mh/ha			
Plant production (nursery)		50.8	
Implanting		150.1	
<u>Fertilization (NPK)</u>			
Average: Formulation		N_7 P_{23} K_7	
Quantity	kg/ha	207.8	
N	kg/ha	14.5	
P	kg/ha	47.8	
K	kg/ha	14.5	
Phosphate as Substit. for NPK	kg/ha	300.0	sandy clay
			clay soil
Pesticides	kg/ha	2.0	
<u>Machine hours</u>			
Plant production	kg/ha	2.0	
Implanting	Eh/ha	16.1	
Fuel	kg/ha	762.0	

TABLE 3-39

Wood Productive Cycle

Technical Aspects

GROWING PHASE (1)

Growing period -- years (y)		18
Growing period between cuts -- years (y)		06
Cuts per growing period		03
Manhours (Average)	Mh/ha	141.5
Machine hours	Eh/ha	7.8
Fuel	kg/ha	65.5
Fertilization (NPK)		
Average: Formulation		N_{20} P_0 K_{19}
Quantity	kg/ha	158.5
N	kg/ha	35.0
P	kg/ha	0.0
K	kg/ha	30.0
Phosphate	kg/ha	400.0
Pesticides	kg/ha	16.2

TABLE 3-40

Wood Productive Cycle

Technical Aspects

GROWING PHASE (2)

Average sun hours per year	h/y	2500
Total sun hours for the growing period	h	45000
Sun hours between cuts	h	15000
Sun energy per ha per year	TJ/ha.y	68.8
Sun energy per ha between cuts (6 y period/cut)	TJ/ha.cut	412.8

Productivity:

Region		$m^3s/ha.y$	mm/y
MG		32.3	1142
Ne	L	10.8	600
	H	38.2	1165
	A	26.2	923

TABLE 3-41

Wood Productive Cycle

Technical Aspects

HARVESTING PHASE (1)

Productive cycle	y	18
Cuts per productive cycle		03
Period between cuts	y	06
Manhours Mh/ha (Average)	327.2	
Machine hours (Average)	Eh/ha	196.7
Fuel	kg/ha (25)	842.2

Productivity (Volume):

Region		m^3_{sol}/ha.y	m^3_{sol}/ha.cut	m^3_{sol}/ha.cut		
				1°	2°	3°
MG		32.3	193.8	222.9	200.6	160.5
Ne	L	10.8	64.8	74.5	67.1	53.7
	H	38.2	229.2	263.4	237.0	189.6
	A	26.2	157.2	180.8	162.7	130.2

TABLE 3-41 -- Continued

Productivity (Weight):

Region		m^3_{sol}/ha.y	tw/ha.y (-DRY)	tw/ha.y (30% MOIST)
MG		32.3	16.2	23.1
Ne	L	10.8	5.4	7.7
	H	38.2	19.1	27.3
	A	26.2	13.1	18.7

HARVESTING PHASE (2)

Harvesting residues (Branches and leaves)

Total Residue:

Region		m^3_{sol}/ha.y	t/ha.y (DRY)	t/ha.y (30% MOIST)
MG		32.3	3.2	4.6
Ne	L	10.8	1.1	1.5
	H	38.2	3.8	5.5
	A	26.2	2.6	3.7

Residue per ha per cut:

Region		m^3_{sol}/ha.cut	t/ha (DRY)	t/ha (30% MOIST)
MG		193.8	19.2	27.6
Ne	L	64.8	6.6	9.0
	H	229.2	22.8	33.0
	A	157.2	15.6	22.2

TABLE 3-42

Wood Productive Cycle

Technical Aspects

TRANSPORTING

Average distance	km:	1	50-70	
Manhours:	Mh/ha	210	(30 m^3_{sol}/ha.y)	
Machine hours:	Eh/ha	36.1	(30 $M3_{sol}$/ha.y)	
Fuel	kg/ha	599.3		
Transport Volume:)		MG	Ne (A)	30 m^3_{sol}/ha.y
(steres)	m^3st/ha	829.8	673.2	771.4
	m^3st/ha.y	46.1	37.4	42.9
	m^3st/ha.cut	276.6	224.4	257.1
Transport Weight: (33% moist)				
	T/ha	415.8	336.6	383.4
	T/ha.y	23.1	18.7	21.3
	T/ha.cut	138.6	112.2	127.8

Research and Development (24):

Manhours	Mh/ha	88.7

Administration:

Manhours	Mh/ha	23.0
Staff (25%)		5.8
	TOTAL:	28.8

TABLE 3-43

Wood Productive Cycle

Technical Aspects

CHARCOAL PRODUCTION (25;23)

Batch process -- 08m Pyrolysis Ovens

Productivity Per:		tw	ha.cut	ha.y
Moisture (% wet basis)		15	--	--
Charcoal	Te	0.328	42.3	7.1
Tar prod.	(kg_T)	127.5	16447.5	2741.3
Recovery	(kg_T)	17	2193	365.5
Max.Recov	(kg_T)	30	3970	645
Residues	(kg):			
Gases				
	CO_2	85	10965	1827.5
	CO	55.3	7134	1189
	C_xH_y	17.9	2309	384.9
Water vapor	m^3	270	34830	5805.0
Liq. of Pyrolysis		263.5	33992	5665.3
Water Regulation	m^3	0.143	18.4	3.1
Electric.	kwh	5.1	657.9	109.7
Fuel	kg			
Manhours	mh	2.25	290.5	48.4

TABLE 3-43 -- Continued

Typical Charcoal Productive Cycle

Pyrolysis kiln diameter	8m
Loading/Unloading	14h
Pyrolisis	111h
Cooling	96h
Total	222h

TABLE 3-44

Wood Productive Cycle

Technical Aspects

ELECTRICITY PRODUCTION

Steam cycle: CST - (Typical installation characteristics):

Installed Capacity		MW	50		
Steam:	Pressure	MPa	6.0		
	Temperature	°C	480		
	Flow	t/h	245.7		
Overall Eff.:		%	21		
Wood consumption		tw/h	78		
Supply Area		ha	27013	Cap Factor: 0.85	
Water Require.		m^3/h			
	Make-up		12.3 - 24.6	Average: 18.5	
	Cooling		14030		
Residues:					
	Ash	t/h	0.78		
	Comb. Eff.	%	100	95	90
	CO_2	T/h	94.4	88.9	85.0
	CO	T/h	--	3.0	6.0
	NO_x				
	Vapour	T/h	25.7	25.7	25.7

TABLE 3-44 -- Continued

Production parameters:

		per tw	per ha.cut	per ha.y
Electricity production	MWh	0.64	82.6	13.8
Manhours	Mh	0.65	83.9	14.0
Water	m^3			
Makeup		0.237	30.6	5.1
Cooling		179.87	23203	3867.2
Steam Cycle:				
Residue *				
Ash	kg*	10	1290	215
CO_2	T_{co2}	1.14	147.1	24.5
CO	kg_{co}	39.1	5044	840.7

* 95% Combustion eff.

TABLE 3-45

Wood Productive Cycle

Technical Aspects

ELECTRICITY PRODUCTION

Gasification -- Gas turbine cycle.

Open Cycle: GTOC

Installed capacity	MW_e	50
Overall effect	%	25
Wood consumption	tw/h	65.5
Energy input	MW_t	200
Gas product	m^3/h	108623
Supply area	ha	22684
Residues:	t/h	
Ash		0.655
CO_2		79.3
CO		--
NO_x Vapour		21.6

TABLE 3-45 Continued

Production parameters:

		per tw	per ha.cut	per ha.y
Electricity production	MWh	0.763	98.4	16.4
Manhours	Mh	0.317	40.98	6.8
Water reg.	m^3	--	--	--
Gas product	Nm^3	1658	213882	35647
Residues:				
Ash	kg	10	1290	215
CO_2	T_{co2}	1.21	156.1	26
CO		--	--	--
NO_x Vapour	T_y	0.33	42.6	7.1

Remarks: Basic G.T LM 2500 GE (37)
Gasification eff. 75%
Forest productivity 30 m^3_{sol}/ha.y

TABLE 3-46

Wood Productive Cycle

Technical Aspects

ELECTRICITY PRODUCTION

Gasification - Gas turbine cycle.

Steam Injected Cycle: BIG STIG

Installed capacity	MW	50	Steam: (37) production t/h 32.3 pressure MPa 3.0 temperature °C (427)
Overall eff.	%	35	
Wood consumption	tw/h	46.3	
Energy input	Mw_t	142.8	
Gas production	m_3/h	89.081	
Supply area	ha	16035	
Residues	t/h		
Ash		0.46	
CO_2		56	
CO		--	
NO_x			
Vapour		15.3	
Water requirements	m^3/h	32.3	

TABLE 3-46 -- Continued

Production parameters:

		per tw	per ha.cut	per ha.y
Electricity production	MWh	1.08	139.3	23.2
Manhours	Mh	0.33	42.6	7.1
Water regulation	m^3	0.74	95.5	15.9
Gas production	Nm^3	1924	248196	41366
Residues				
Ash	kg	10	1290	215
CO^2	t_{CO2}	1.21		
CO	t_{co}			
NO_x				
Vapour	t_v	0.33	42.6	7.1

Remarks: Basic G.T: LM 2500 - GE
Gasification eff.: 87 %
Forest production: 30 m^3_{sol}/ha.y

TABLE 3-47

Wood Productive Cycle

Technical Aspects

ELECTRICITY PRODUCTION

Gasification -- Gas turbine cycle.

Combined Cycle: BIG-GTCC

Installed capacity	MW	50	Water Reg. (37) Make-up m^3/h 2.8-5.6
Overall eff.	%	40	Cooling m^3/h 3200
Wood consumption	tw/h	40.5	
Energy input	MW_T	125	
Gas production	m^3/h	74318	STEAM Product. t/h≈56
Supply area	ha.	14026	Pressure MP_a 3.0 Temp. °C ≈425
Residues:	t/h		
Ash		.40	
CO_2		49	
CO		--	
NO_x			
Vapour		13.4	

TABLE 3-47 -- Continued

Production parameters:

		per tw	per ha.cut	per ha.y
Electricity	MWh	1.233	159.3	26.6
Manhours	Mh	0.369	47.6	7.9
Gas production	Nm^3	1835	236715	39453
Water req.	m^3	79.1	10204	1701
Residues:				
Ash	kg	10	1290	215
CO_2	t_{co2}	1.21	156.1	26
CO	t_{co}			
NO_x	t_{nox}			
Vapour	t_y	0.33	42.6	7.1

Remarks: Basic GT.: LM 2500 GE
Gasif. eff. 83%
Forest product. 30 m^3_{co1}/ha.y

TABLE 3-48

Wood Processing Cycle -- Environmental Aspects.

Phase:	Main Causes of Impact:	Effects on the Environment:
Implanting and Growing	Over-fertilization. Over-use of pesticides and formicides. Soil erosion. Modification of habitat conditions.	Leaking of fertilizers to rivers or water and manipulation hazards. Loss of soil. Soil carry-over and sedimentation in rivers or lakes.
Harvesting	Soil erosion or soil damage by tractors and trucks.	Loss of soil.
Processing:		
Charcoal	Tars, CO_2, CO, hydrocarbons, and pyrolysis liquids. Charcoal dust/fine material-particulates	Air pollution; by gases and particulates. Pollution of rivers and of other water courses by tars and pyrolysis liquids.

TABLE 3-48 -- Continued

Electricity	CO_2, CO, NO_x, water treatment chemicals. hydrocarbons, particulates heat release, cooling water chemicals.	Air pollution. leaking of chemical products to rivers or water courses. Increase in water temp. of rivers used for cooling purposes.

TABLE 3-49

Wood Productive Cycle - Social Aspects.

AGRICULTURAL AND TRANSPORT JOBS

Phase	Mh/ha	Prod. hours h/y	cycle y	Employed persons M/ha
Plant Production	50.8	2024	18	0.0014
Implanting	150.1			0.0041
Growing	141.5			0.0039
Harvesting	327.2			0.0090
Transport	210.0			0.0058
Administration	28.8			0.0008
R and D	88.7	2024	18	0.0024
TOTAL:	997.1	2024	18	0.0274

TABLE 3-50 WOOD PRODUCTIVE CYCLE SOCIAL ASPECTS - PROCESSING JOBS

	$\frac{Mh}{ha.y}$	$\frac{h}{y}$	$\frac{M}{ha}$
Charcoal	48.4	2024	0.024
Electricity			
Steam	14	2024	0.0069
GT	6.8	2024	0.0034
STIG	7.1	2024	0.0035
Comb. Cycle	7.9	2024	0.0039

TABLE 3-51 WOOD PRODUCTIVE CYCLE SOCIAL ASPECTS
TOTAL JOBS

	M/ha		
	Processing	Agricultural	Total
Charcoal	0.0240	0.0274	0.0514
Elect. Steam	0.0069	0.0274	0.0343
Elect. GT	0.0034	0.0274	0.0308
Elect. STIG	0.0035	0.0274	0.0309
Elect. C.C.	0.0039	0.0274	0.0313

TABLE 3-52 WOOD PRODUCTIVE CYCLE ECONOMIC ASPECTS AGRICULTURAL AND TRANSPORT COSTS - 1988

		BR	MG	Ne
Land * \$/ha	100-300	30	32.6	26.2 (m^3_{sol}/ha.y)
Plant Prod. \$/ha	90.20			
Implant \$/ha	367-811			
Growing \$/ha	336.20			
Harvest \$/m^3_{sol}	3.30	1782.0	1919.6	1556.3
Adm. \$/ha	52.60			
R & D \$/ha	125.80			
Transport \$/m^3_{sol} (Aver. Dist. 70 km)	3.06	1652.4	1779.1	1443.1

* Assumed Values

Obs. 3 cuts
6 years between cuts
18 years productive cycle

TABLE 3-53 WOOD PRODUCTIVE CYCLE ECONOMIC ASPECTS
AGRICULTURAL AND TRANSPORT COST DISTRIBUTION 1988 (A)

YEAR	Cost Distribution			
0	Land - Plant Prod. Implant.		Adm.	R & D
1	Growing			
2				
3				
4				
5				
6		Harvesting Transp.		
7				
8				
9				
10				
11				
12		Harvesting Transp.		
13				
14				
15				
16				
17				
18	Growing	Harvesting Transp.	Adm.	R & D

Table 3-54 WOOD PRODUCTIVE CYCLE
ECONOMIC ASPECTS
AGRICULTURAL AND TRANSPORT COSTS DISTRIBUTION - 1988 (B)
$/ha

Year	Land *	Plant Prod.	Implant.	Grow.	Adm.	R&D	Harv. + Transp. BR	Harv. + Transp. MG	Ne
0	100-300	90.2	367-811		18.8				
1				18.7	1.9	7.0			
2									
3									
4									
5									
6							1316	1417	1149
7									
8									
9									
10									
11									
12							1185	1276	1034
13									
14									
15									
16									
17									
18				18.7	1.9	7.0	95.0	1020	828

*Assumed value; Remarks: 1° cut 100%, 2°cut 90%, 3°cut 72%; 1°cut 1.15 av. yield.

TABLE 3-55 WOOD PRODUCTIVE CYCLE
ECONOMIC ASPECTS
AGRICULTURAL AND TRANSPORT COSTS
ANNUAL DISTRIBUTION - 1988 $/ha

	BR		MG		Ne	
Year	L	H	L	H	L	H
0	576	1220	576	1220	576	1220
1	27.6		27.6		27.6	
2						
3						
4						
5	27.6		27.6		27.6	
6	1343.6		1444.6		1176.6	
7	27.6		27.6		27.6	
8						
9						
10						
11	27.6		27.6		27.6	
12	1211.6		1303.6		1061.6	
13	27.6		27.6		27.6	
14						
15						
16						
17	27.6		27.6		27.6	
18	977.6		1047.6		855.6	

TABLE 3-56 WOOD PRODUCTIVE CYCLE
ECONOMIC ASPECTS
INVESTMENT COSTS FOR CHARCOAL PRODUCTION

(1) Batch Process 1988

Charcoal

Kiln diameter	(m)	05	08
Annual production	(t_c/y)	150	800
Life Time	y	04	04
Invest. Cost	$/kiln	2750	14450

Tar Recuperation

Annual Production	1T/y	800
Life Time	y	20 (estimated)
Investment Cost	$	131910.00

(2) Continuous Process

2.1	Production Charcoal	t_c/y	15000 (Retort - 1)
	Tar	t_T/y	3100
	Pyrolysis H.C.	t_P/y	-
	Life Time	y	30
	Invest. Cost	$	4922000.00
2.2	Production Charcoal	t_c/y	15000 (Retort - 2)
	Tar	t_T/y	3100
	Pyrolsis H.C.	t_p/y	800
	Lifetime	y	30
	Invest. Cost	$	7656450.00

TABLE 3-57 WOOD PRODUCTIVE CYCLE
ECONOMIC ASPECTS
OPERATIONAL COSTS FOR CHARCOAL PRODUCTION

(1) Batch Process (35) - 1988 US$

	$/tw	
kiln diam. (m) →	5.0	8.0
Pyrolsis op. cost	1.65	1.15
Financial cost	1.42	0.80
Tax Expenses	0.14	0.14
Insurance & Other costs	4.16	2.90
Charcoal Transp. (up to 50 km)	1.65	1.65
Moving of wood & charcoal at the charcoal prod. facilities	0.73	0.73

Remarks: Charcoal production rate: 0.328 t_c/t_w
US$ adjustment factors: 1985 110.90; 1988 121.3
Wood: air drying period - 120 - 150 days
moist content ≈ 27.30 %

TABLE 3-58 WOOD PRODUCTIVE CYCLE
ECONOMIC ASPECTS
OPERATIONAL COSTS FOR CHARCOAL PRODUCTION

(2) Continuous Process (35) - 1988 US$

		$/tw
Personnel		2.58
Maintenance		2.69
Electricity		1.51
Adm.		1.79
Capital - Finance		
2.1)	Retort - 1	
	Deprec.	3.59
	Amort. + Int.	13.34
2.2)	Retort - 2	
	Deprec.	5.58
	Amort. + Int.	20.78

Remarks:

Elect. 60.4 kwh/tw - 25 $/MWh
Inter. Rate 12% P.Y.
Deprec. - Constant on an annual basis
Lifetime - 30 y
Wood consump: 45730 t_w/y (15000 t_c/y)

TABLE 3-59 WOOD PRODUCTIVE CYCLE
ECONOMIC ASPECTS
OPERATIONAL COSTS FOR TAR RECUPERATION
BATCH PROCESS (1988 $) (35)

	$\$/t_t$	$\$/t_w$
Personnel	6.41	0.35
Maintenance	4.95	0.27
Electricity	0.72	0.04
Financial Costs:		
Depreciation	8.23	0.45
Amortiz. + interest	22.1	12.08

Remarks: Electricity - 375 kwh/t_t or 20.5 kwh/tw

Electr. cost - 25$/MWh

Life time - 20 years

Interest rate - 12% per year

Depreciation: Const. annual rate

Maint. 3% of Invest. 0.0547 T_t/T_w

Tar production 0.0547 t_T/t_w

TABLE 3-60 WOOD PRODUCTIVE CYCLE
ECONOMIC ASPECTS
INVESTMENT COSTS 1988 $
STEAM CYCLE 50 MW (2 x 25 MW) (35) CST

		$/kw
#Power Plant		
·Equipment		
·Generation		
Boiler	464	798
Turbo generator	285	
Piping	49	
·Electrical and Substation		60
·All Others		86
·Civil works assembly		241
#Wood Storage, Handling and Preparation		
·Equipment		121
·Civil works assembly		69
#Transp and Insurance		71
#Engineering		145
#Adm. Costs		159
#Contingency		175
#Erection Period Interest		416
Total Invest. Cost		2341

Remarks: Constr. Period - 3y
Inter. Rate - 10% per y.
Life time - 25y

Pay. sch.: 1°y - 30%
2°y - 45%
3°y - 25%

TABLE 3-61 WOOD PRODUCTIVE CYCLE
ECONOMIC ASPECT
INVESTMENT COSTS

GASIF - Gas Turbine Cycle 50/60 MW (3 x 20 MW) 1988$	BIG-GTOC		
Fuel Handling/gasification (14)	$/kw		
Fuel handling	42.2		
Blast air system	14.4		
Gasification plant	171.5		
Gas physical clean-up	9.4	237.5	237.5
Gas Turbine Plant Equip. (38)			
G.T. gen set pack.	350		
Auxiliary system	15	365	602.5
Electrical Equip. (38)			
Subst. TRAFOS	15		
Swit. gear; control grid intercon.	25	40	642.5 A
Install; Eng; Adm.			
Eng. services	25		
Civilworks assembly	100	125	727.5 B
Transp. & Insur. 2-2.5%A	15		
Contingency 10%B	73		815.5
Erection period interest 18%B	131		946.5

Remarks:

2.5 years erection	1°S - 15% Paym.
10% y interest	2°/3°S - 50% Paym.
Lifetime 25y	4°/5°S - 35% Paym.

TABLE 3-62 WOOD PRODUCTIVE CYCLE
ECONOMIC ASPECTS
INVESTMENT COSTS
GASIF - GAS TURBINE CYCLE - STIG (50/60 MW) BIG-STIG
(2 x 30 MW) 1988$

	$/kw		
Fuel Handling/gasification (14)			
Fuel handling	42.2		
Blast air system	14.4		
Gasification plant	171.5		
Gas physical clean-up	9.4	237.5	237.5
Gas Turbine Plant Equip. (38)			
G.T. gen set pack.	350		
Auxiliary system	15	365	602.5
Steam Equipment			
HRSG	80		
Water treat, pumps,etc	25	105	707.5
Electrical Equip.			
Subst. TRAFOS	15		
Swit. gear; control grid intercon.	25	40	747.5 A
Install; Eng; Adm.			
Eng. services	36		
Civilworks assembly	117		900.5 B
Transp. & Insur. 2-2.5%A	17		
Contingency 10%B	90		
Erection period interest 18%B	162		1169.5

Remarks:
2.5 years erection — 1°S - 15% Paym.
10% y interest — 2°/3°S - 50% Paym.
Lifetime 25y — 4°/5°S - 35% Paym.

TABLE 3-63 WOOD PRODUCTIVE CYCLE
ECONOMIC ASPECTS
INVEST. COSTS
GASIF - GAS TURB. COMBINED CYCLE (60 MW) BIG-GTCC
(2 x 20 MW GT + 1 x 20 MW ST) 1988$

Fuel Handling/gasification (14)		$/kw		
	Fuel handling	42.2		
	Blast air system	14.4		
	Gasification plant	171.5		
	Gas physical clean-up	9.4	237.5	237.5
Gas Turbine Plant Equip. (38)				
	G.T. gen set pack (350.2/3)	233		
	Auxiliary system (15.2/3)	10	243	480.5
Steam Equipment (38)				
	HRSG (80.1/3)	26.7		
	Water treat (15.1/3)	5.0		
	Cond.; Pumps etc. (20.1/3)	6.7		
	Steam TurbGen.Piping(35)(334.1/3)	111.3	149.7	630.2
Electrical Equip.				
	Subst. TRAFOS	15		
	Switch gear; control	30	45	675.2 A
	grid connect			
Install; Eng; Adm.				
	Eng. services	34		
	Civilworks assembly	135		844.2 B
	Transp. Insur. 2-2.5%A	15		
	Contingency 10%B	85		
	Erection period interest 20%B	169		1113.2

Remarks: 3.0 years erection period — 1°y 20%pay
10% y interest — 2°y 50% pay
Lifetime 25 y — 3°y 30% pay

TABLE 3-64 WOOD PRODUCTIVE CYCLE
ECONOMIC ASPECTS
OPERATIONAL COSTS (14)

Steam Cycle - CST	
Fixed Costs 10^3\$/y	Variable Costs \$/kwh
2 x 664 + 129.7 = 1457.7	0.003

Gasification Gast Turbine Cycle	BIG GTCC
Fixed Costs 10^3\$/y	Variable Costs \$/kwh
1304 + 297 = 1601	0.001

Gasification - STIG or Comb. Cycles	BIG-STIG and BIG GTCC
Fixed Costs 10^3\$/y	Variable Costs \$/kwh
1304 + 297 = 1601	0.001

TABLE 3-65 WOOD PRODUCTIVE CYCLE

ENERGY BALANCE

ENERGY INPUTS

Agricultural and Transp. phases

	MJ/t_w	
Manuf. of Agric. Equip.	56.7	
Fuel	351.9	
N fertilizer	7.6	
P	7.2	
K	1.85	
Phosphate	38.1	
Pesticides	0.2	453.55
Processing phase	113.5	577.05
Sun Energy	4.59×10^6	

TABLE 3-66 WOOD PRODUCTIVE CYCLE
ENERGY BALANCE
ENERGY OUTPUTS

	MJ/t_w
Wood (dry: 30 m^3_{sol}/ha.y	17600
Charcoal + Tar	12954
Electricity	
Steam cycle	3696
GT - open	4400
STIG - cycle	6160
Comb. cycle	7040

Table 3.67

VEGETABLE OIL PRODUCTIVE CYCLE

Technical Aspects

PALM OIL (42)

IMPLANTATION PHASE (1° YEAR)

Plant spacing	10m x 7m
	8,5m x 8m
Plants per ha	143-145

Manhours	Mh/ha	(42)	(43)	A
Plant Product (Nursery)			96	84
Implanting			1232	1076
Total		1000	1328	1160
Fertilizer	kg/na			
Plant Product. (Nursery)			36	
Implanting			139	
Pesticides	kg/na		2.5	
Machine hours	Eh/ha			
Fuel	kg/ha			

Table-3-68

VEGETABLE OIL PRODUCTIVE CYCLE

TECHNICAL ASPECTS

PALM OIL (42)

GROWING PHASE

Growing period

Improductive years	(y)			04* - 05
Productive years	(y)			21* - 25
Growing period. between cuts	(y)			24* - 30
		(42)	(43)	A
Man-hours	Mh/ha.y	156	318	237
	Mh/ha	3744	7632	5688
Machine hours	Eh/ha	Eh/ha.y		
Fuel	kg/ha	kg/ha.y		
Fertilizers	kg/ha.y	125 - 975 352	Major Producers Brazil	
	t/ha	3 - 23.4 8.8	Major Producers Brazil	
Herbic.+ Pestic.	kg/ha.y	4.5		
Minimum sun hours per year	h/y	1825		
Minimum sun hours per day	h/d	5		
Available sun hours (average)	h/y	2500		
Sun energy, per ha, per year: (average available energy)	TJ / ha.y	68.8		

Table 3-68 Cont.

Rainfall Requirements			
Annual minimum	mm/y	>2000	
Monthly Minimum	mm/month		> 100
Max. acceptable dry period	month/y	03	

Soil Requirements: major constrains drainage; flatness. Soils not suitable for palm oil tree; lateritic with ironstone concretions, coastal sandy soils anda deep peat soils.

Temperature Requirements:	Mean Max.	29-33	C
	Mean Min.	22-24	C

Altitude < 400 M

Table-3-69

VEGETABLE OIL PRODUCTIVE CYCLE

TECHNICAL ASPECTS

PALM OIL

HARVESTING PHASE

Palm tree life cycle - y		25			
Productive period - y		21			
Productivity -	tb/ha.y	23 (see appendix for details)			
	tb/ha	473			
Manhours		(42)	(43)		
	Mh/tb	10.4-18.4			
	Mh/ha.y	239-423	180		
	Mh/ha	5023-8887	4500		
Averages					
	Mh/ha.y	331		180	256
	Mh/ha	6955	4500	5728	
Machine hours	Eh/ha		Eh/ha.y		
Fuel	kg/ha		kg/ha.y		

Table 3-70

VEGETABLE OIL PRODUCTIVE CYCLE

TECHNICAL ASPECTS

PALM OIL (42)

TRANSPORTING

Period per productive cycle-y		21
Average distance-Km		< 15 km
Manhours	Mh/ha	386.4
Machine hours	Eh/ha	16.6
Fuel	kg/ha	188.8
Transport vol.	m^3/ha	
Weight	t/ha	483
	t/ha.y	23

R & D

Manhours	Mh/ha	--

Administration (42)

Man-hours (2.5% Total task force)	Mh/ha	247-468

Table 3-71

VEGETABLE OIL PRODUCTIVE CYCLE

TECHNICAL ASPECTS

PALM OIL (42)

PROCESSING PHASE - BUNCHES

	per:	tb	ha.y	ha
Oil product	to	0.24	5.5	115.9
Meal product	tm	0.025	0.58	12.1
Required				
Water	m^3			
Steam	t_{st}			
Electric	Kwh	5	115	2415
Residues				
Nutshells	tns	0.06	1.38	29.0
Fibre	tf	0.325	7.5	157.0
Manhours	Mh	2.2-3.1	50.6-70.9	1063-1489

Table 3-72

VEGETABLE OIL PRODUCTIVE CYCLE

TECHNICAL ASPECTS

PALM OIL

PROCESSING PHASE - OIL

Transesterification

Process (M)

Inputs			Per	
		tb	ha.y	ha
Palm oil	to	0.24	5.52	115.9
Methanol	$t(CH_3OH)$	0.12	2.76	58.0
Potash hydroxide	kg(KOH)	2.4	55.2	1159.2
Electric Energy	Kwh	0.72	16.56	347.8
Outputs				
Methylester	t_{me}	0.24	5.52	115.9
Glycerin	kg_G	24	552	11592
Fatty Acids	kg_{fa}	12	276	5796
Hydrous Alcohol	kg_A	72	1656	34776
Residue	kg_R	14.4	331	6951
Manhours	Mh	7.7	177.1	3719.1

Table 3-73 VEGETABLE OIL PRODUCTIVE CYCLE

PALM OIL

ENVIRONMENTAL ASPECTS - AREAS OF CONCERN

PHASE	MAIN CAUSES OF IMPACT	EFFECTS ON THE ENVIRONMENT
Implanting	Overfertilization	Contamination of rivers and other water sources from leaching of fertilizers
Growing	Overfertilization Over use of pesticides and herbicides	Same as above
Harvesting	Bunches handling by trucks and tractors	Soil damage, soil compactation
Processing	Poor burning of residues, residue disposal	Air pollution by particulates local impact

Table 3-74 VEGETABLE OIL PRODUCTIVE CYCLE
PALM OIL
SOCIAL ASPECTS - JOBS (AVERAGE VALUES)

Phase	Mh/ha	h/y	y	M/ha	Total
Plant Prod. (nursery)	84.0	2024	25	0.0017	
Implanting	1076.0			0.0213	
Growing	5688.0			0.1124	
Harvesting	5728.0			0.1132	
Transporting	386.4			0.0076	0.2562
Processing					
Bunches	1276.0			0.0252	0.2814
Oil (Transest. pr)	3719.0	2024	25	0.0735	0.3549
Total	17957.4			0.3549	

Table 3-75

VEGETABLE OIL PRODUCTIVE CYCLE

PALM OIL

ECONOMIC ASPECTS

Investment Costs	$/ha 1988
Field Establishment(42)	3909
Oil Mill(42)	1460
Vehicles(42)	160
Buildings(42)	608
Total (42)	6137
(44)	7000

Remarks: See Appendix for details
No information was found about transesterfication plants for large sizes

Table 3-76

VEGETABLE OIL PRODUCTIVE CYCLE

PALM OIL

ECONOMIC ASPECTS

PRODUCTION COSTS (1988)

Ref. (42)

Item	$/tb	
Maintenance	15.3	
Harvesting	11.9	
Transport.	3.9	
Processing	11.8	
Distribution	2.3	
Overhead	9.5	
Interest	21.0	
Depreciation	25.2	
Total	100.9	
Aver. Oil Extrac. to/tb	0.243	
Prod. Cost Per to $/to T.of Oil	415.4	
Ref. (44)	Brazil	Malaysia
Prod. Cost Per t of Oil $/to	270	200

Remarks: No information was found about tranesterification plants for large units or commercial plants.

TABLE 3.77 ALTERNATIVES FOR ALCOHOL AND VEGETABLE OILS AS SUBSTITUTE FOR DIESEL, FROM THE TECHNICAL STAND POINT (45); (46)

Fuel	Substitution Alternative	Development Stage
Alcohol	Mixture of anhydrous alcohol up to 35%	Commercial
	Double injection motors	Commercial
	Use of hydrous alcohol with additives	Commercial
Vegetable Oil	Mixture up to 20%	Pre-commerical
	Double injection	Commercial
	Production and use of esters from vegetable oils	Pre-Industrial
	Catalytic cracking of up to 10% mixtures in petroleum refineries	Industrial
	Direct catalytic cracking	Research and Demonstration

TABLE 3.78 PHYSICO CHEMICAL PROPERTIES OF DIESEL OIL VERSUS VEGETABLE OILS

	Diesel	Veg. Oil Esters	Vegetable Oils	
cetane index	45-48	51	36-41	
kinematic viscosity-cst at 37.8°C	1.8-5.8	4.7	27.3-41.2	Castor Oil 290
at 98.9°C	---	---	6.2-8.8	Castor Oil 19.9
Sulfur content (weight %)	1.3 max	---	< 0.1	
Melting point °C	---	---	-21; +21	
Flash point °C	55	153	188-332	
Specific Gravity 15°C/4°C	0.828	0.884	0.911-0.96	
HHV MJ/kg	45.5	44.7	37.4-40.7	
LHV MJ/kg	42.3	42.0*	34.9-37.0	
Carbon content (weight %)	86	77.0*	73.9-77.6	
Hydrogen content (weight %)	13	13.0	11.9-12.1	

* Estimated

TABLE 3.79 CONSUMPTION DATA (39) (SEE APPENDIX 3-4 FOR DETAILS)

TRUCK-TRACTOR DIESEL MOTORS

Volumetric Consumption (%)

Fuel	
Diesel	100
Alcohol/Additives	160

Energy Consumption (%)

Fuel	
Diesel	100
Vegetable oil	130

Mass Consumption (%) (measure basis gr./cv.h)

Fuel	
Diesel	100
Vegetable oil ester	90
70% diesel/30% veg. oil	92
100% veg. oil	110-128

CAR DIESEL MOTORS

Volumetric consumption (%) - (measur. basis l/100 km)

Fuel	%	
Diesel	100	
70% diesel/30% veg. oil	100	
100% veg. oil	82	(average city-highway)
veg. oil ester	105	

Remarks: 1cv = 0.7351 kw
1hp = 0.7453 kw

TABLE 3.80 DIESEL CONSUMPTION EVOLUTION IN BRAZIL 1983-1988

Year	1000 m^3	%
1983	17584.8	
		7.62
1984	18924.1	
		6.40
1985	20135.8	
		11.02
1986	22353.2	
		5.96
1987	23684.5	
		1.48
1988	24033.9	

TABLE 3.81 HYDROUS ALCOHOL AS A DIESEL SUBSTITUTE

	100%	30%	10%
1988-1000 m^3	24033.9	7210.2	2403.4
Hydrous alcohol	38453.8	11536.3	3845.4
Sugar cane reg. million t	549.3	164.8	54.94
Sugar cane area million ha	10.6	3.17	1.06

Remarks

70 l/tc
52 tc/hay or 65 t/ha.out
1.6 Palc/pd

TABLE 3.82 BRAZIL REFINING STRUCTURE FOR THE PERIOD 1980-1989

Product	%
LPG	7.8
Light	21.2 (80% gasoline)
Medium	38.8 (95% diesel)
Heavy	32.2

TABLE 3.83 PETROLEUM REFINED 1988 AND MODIFICATIONS IN PRODUCTION AND CONSUMPTION CAUSED BY 10% DIESEL REPLACEMENT WITH ALCOHOL WITH ADDITIVES ($10^6 m^3$)

			Forecast			
			Prod.		Cons.	
	Actual	Forecast	Gas	Diesel	Gas	Diesel
Refined Petrol-eum	68.95	62.28				
LPG	5.38	4.86				
L	14.62	13.20	10.56		11.93	
M	26.75	24.16		22.95		21.63
H	22.20	20.05				

TABLE 3.84 VEGETABLE OIL AS A DIESEL SUBSTITUTE

	100%	30%	10%
Diesel Consump. 1988 - $1000m^3$	24033.9	7210.2	2403.4
Diesel Consump. 1988 - 1000t	19900	5970	1990
Displacement with mixture 70%D/30%V.O.			
Veg. oil req. 1000 t		5492.4	1830.8
Total Mixture 1000 t./y		18308.0	6102.7
Palm oil bunch Prod. req. 1000 t/y		22885.0	7628.3
Area req. ha		995000	331700

Remarks:
Consumpt. Ratio VO-D Mix/D = 0.92
Palm oil extraction rate: 24%
Palm oil bunch prod. - 23 t/hay
Diesel specif. gravity - 0.828 t/m^3

TABLE 3.85 COST; PRICE; DENSITY; HEATING VALUES, FOR DIESEL, ALCOHOL, AND PALM OIL. (39,44,45,47)

Cost (1988 $)		Cost $/t	Price $/t
Palm oil	Brazil	250 - 270	400 - 550
	Malaysia	200	
	World Average	415	300 - 450
Diesel			140 - 150
Alcohol	Brazil	325	

Density	t/m^3
Palm oil	0.92
Alcohol	0.794
Diesel	0.828

Heating values GJ/t

	LHV	HHV
Palm oil	35.1	40.7
Alcohol	26.8	29.7
Diesel	42.3	45.2

Remarks: Alcohol price: 18.08 $/tc (total cost)
70 p/tc
0.794 kg/p

Diesel price: Rotterdam spot market prices

TABLE 3.86 COST/PRICE OF DIESEL ALCOHOL AND PALM OIL ENERGY.

	$/GJ COST	PRICE
Diesel		3.30 - 3.55
Alcohol	12.13	
Palm oil		
Brazil	7.12 - 7.70	11.40 - 15.67
Malaysia	5.70	
World Average	11.82	8.55 - 12.82

Remarks: Based on LHV

TABLE 3.87 PALM OIL SUBSTITUTE FOR DIESEL - ADDITIONAL DATA

Substituted diesel	30%	10%
Diesel 1000 t_D	5970	1990
Diesel cost (\$145 per t_D) million \$	865.65	288.55
Palm oil to be exported to cover the diesel replacem. Expenses based on palm oil price of \$375.00 per t_{po}. (1000 t_{po})	7527	2509
Palm oil bunch prod. required (1000 t_b/t)	31.362	10455
area required 1000 ha	1364	455
Job opportunities created	484100	16.1500
Invest. required \$billions	8.37	2.80
Time required to begin substituting	~5y	~5y

4. PLANTED FORESTS AND SUGAR CANE RESIDUES AS A PRIME SOURCE OF ENERGY FOR ELECTRICITY PRODUCTION IN NORTHEAST BRAZIL - A CASE STUDY

The aim of this chapter is to analyze the possibilities and consequences of using biomass as a prime source of energy to produce electricity in Northeast Brazil.

The basic information for the analysis are the data developed in Chapter 3. The analysis will compromise the following aspects:

Conversion technology
Energy costs
Basic models for biomass electricity development
Electricity generation potential
Income distribution
Economic regional impact versus energy production

The last topic intends to quantify the manpower requirements, investments and new opportunities for development related to the extensive use of biomass for electricity.

4.1 CONVERSION TECHNOLOGIES

The two main technologies considered here for converting biomass or its residues to electricity are conventional steam cycles and advanced gas turbine cycles. The first is commercially available. It is already being used although in some cases inefficiently.

Gas turbine cycles will require some development and demonstration before reaching commercial status, a process which will take between 5 and 7 years if the necessary resources are made available.

It is important to stress that the aim of this section is not to perform a detailed analysis of each technology, but to give a clear idea of what is involved in each case and to show the parameters that will be used as a base for further analysis.

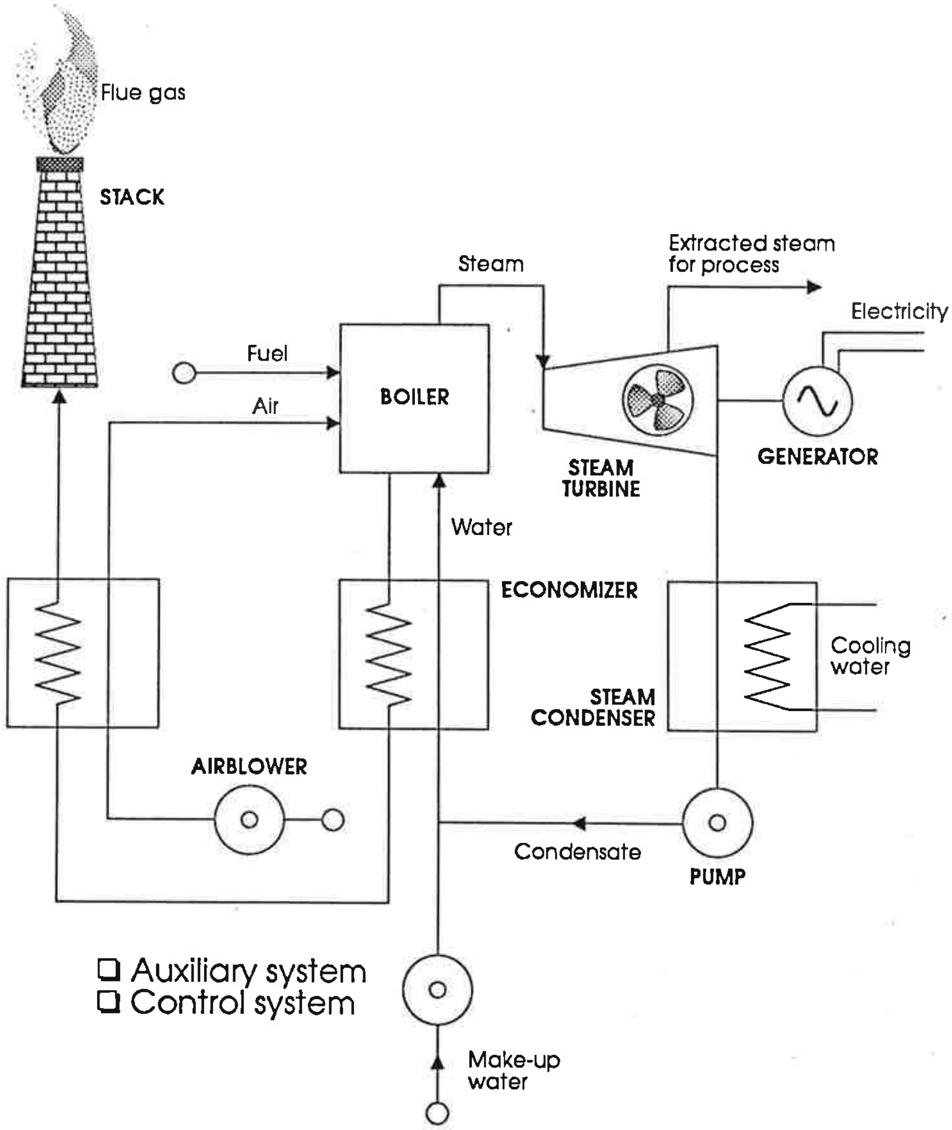
4.1.1 THE STEAM CYCLE TECHNOLOGY

Although many configurations of steam cycles are in use, the focus will be on the one shown in Fig. 4.1. The reason is that this would be the most likely to be used for biomass conversion, mainly in the sugar cane industry. In the case of wood plantations the extracted steam would not be used for process but to raise the condensate temperature to get a better overall efficiency.

The main components of the steam cycle are shown in Fig. 4-1. There are some additionally major electric components such as transformers and breakers that may or may not be included in the steam generation package. In Fig. 4.1 they are not shown for simplicity.

In this study the initials CEST stand for Condensing Extraction Steam Turbine and CST for Condensing Steam Turbine. The present configuration of steam cycles used in the sugar cane industry permits just minimal production of surplus electricity. The analysis here will focus on improved facilities.

The Tables 4.1 and 4.2 show the parameters relating to electricity production that will be considered in further evaluations.



Main components

Steam boiler	Air preheater
Steam turbine	Pumps/piping
Generator	Air blower
Condenser	Stack
Economizer	Auxiliary and control systems

Fig 4.1: Steam cycle · basic components

TABLE 4.1 STEAM CYCLE - BIOMASS - SUGAR CANE ELECTRIC GENERATION PARAMETERS.

Steam pressure range: 6.0 MPa
Steam temperature range: 450 - 480 °C
Required Electricity for Process: 15 kwh/tsc (for sugar cane only)

Fuel	Season	Generation System	Production (kwh/t_{sc})	Surplus (kwh/t_{sc})
Bagasse (50% moist)	On	CEST	100	85 *
	Off	CST	116	116
Tops/Leaves	On	CST	116	116
	Off	CST	116	116 *
Biogas from Stillage	On	CST	11.6	11.6*
	Off	CST	11.6	11.6
Total Electricity			227.6	212.6*

Remarks: * Most likely operational mode

TABLE 4.2 STEAM CYCLE - BIOMASS - WOOD ELECTRIC GENERATION PARAMETERS

Steam pressure range 6.0 MPa

Temperature range 480°C

Required electricity for process ---

Fuel	Generation System	Net Production kWh/t_w
Wood 33% moist	CST	640

4.1.2 THE GAS TURBINE TECHNOLOGY

The use of gas turbines to convert biomass to electricity requires the transformation of the solid biomass into a gas which can be handled by the gas turbine combustion system. It also requires the fuel gas to meet certain specifications for contaminant concentrations:

particulates:	1 - 20 mg/Nm^3, 90% less than 10 μm
alkali:	100 - 200 ppb
tars:	vapor phase

These characteristics and the requirement of achieving maximum overall efficiency pose the most serious challenges to be overcome before this technology reaches commercial status. These are also the reasons a demonstration phase must be successfully completed before it is possible to take advantage of all its benefits, which can be summarized in higher efficiencies and lower costs than steam cycle technology. Additional benefits include the possibility of powering small scale power plants competitively with a natural renewable resource found throughout the world in a modern, efficient and environmentally friendly way. From a social standpoint, the introduction of the biomass gasification/gas turbine technology (BIG/GT) to produce electricity would open a large number of new job opportunities mainly in rural areas.

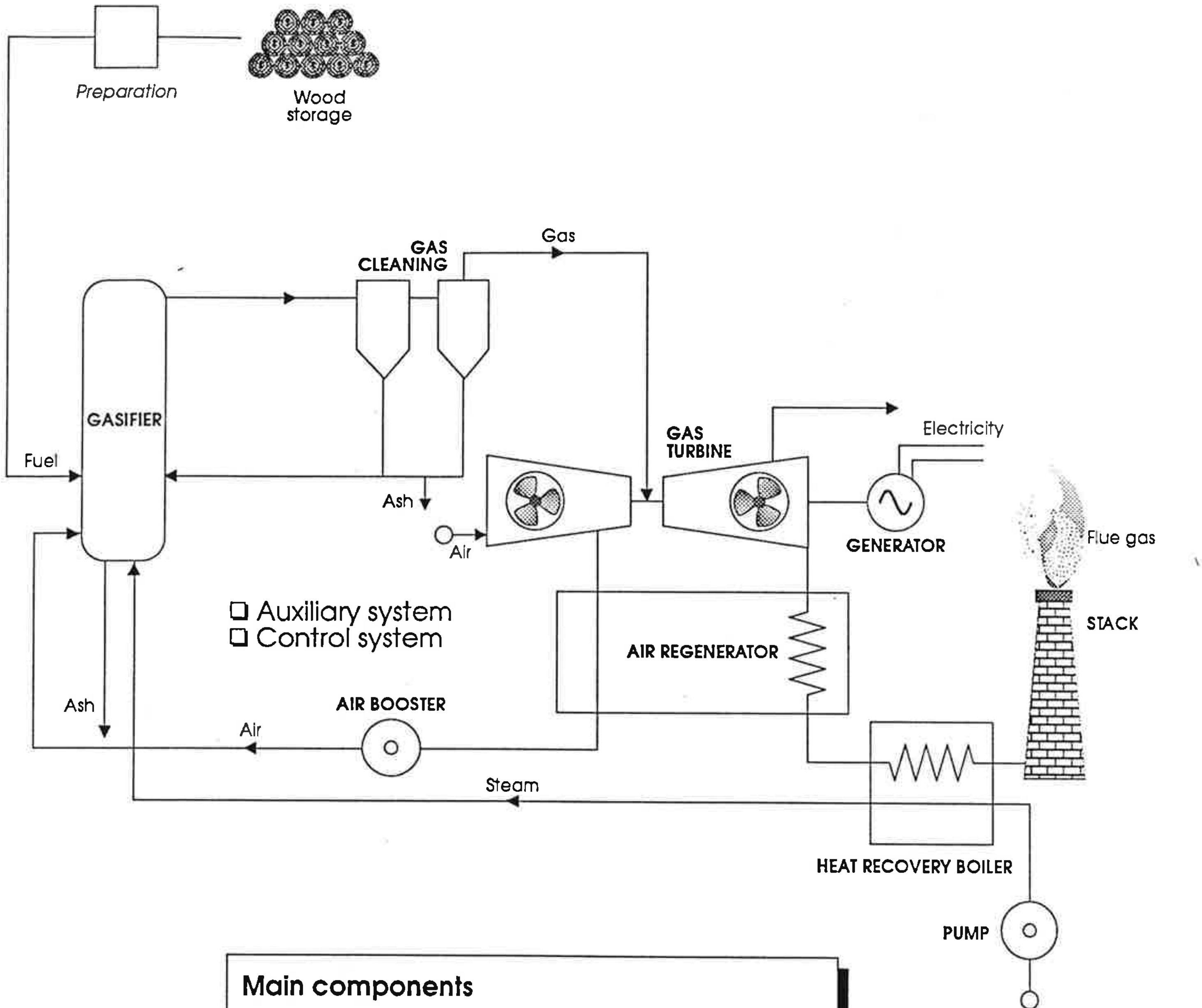
Although studies in the last few years in Brazil, U.S., Finland, Sweden and England have all indicated it is potentially one of the most powerful technologies for producing electricity at low costs, the pace of development of the first demonstration project has been sluggish. Several demonstration efforts have very recently been initiated, however, so it seems conceivable that the technology could be commercially ready within about five years.

The following data are based on the best information available, as drawn from many conceptual studies made about the use of gas turbines for biomass electricity.

The alternatives for using gas turbines with biomass are as follows:

Gasification	- atmospheric or pressurized
G.T. cycles	- open cycle - GTOC
	- steam injected gas turbine - STIG
	- steam combined cycle - G.T.C.C.
	- intercooled steam injected gas turbine - ISTIG
	- air combined cycle - A.C.C.

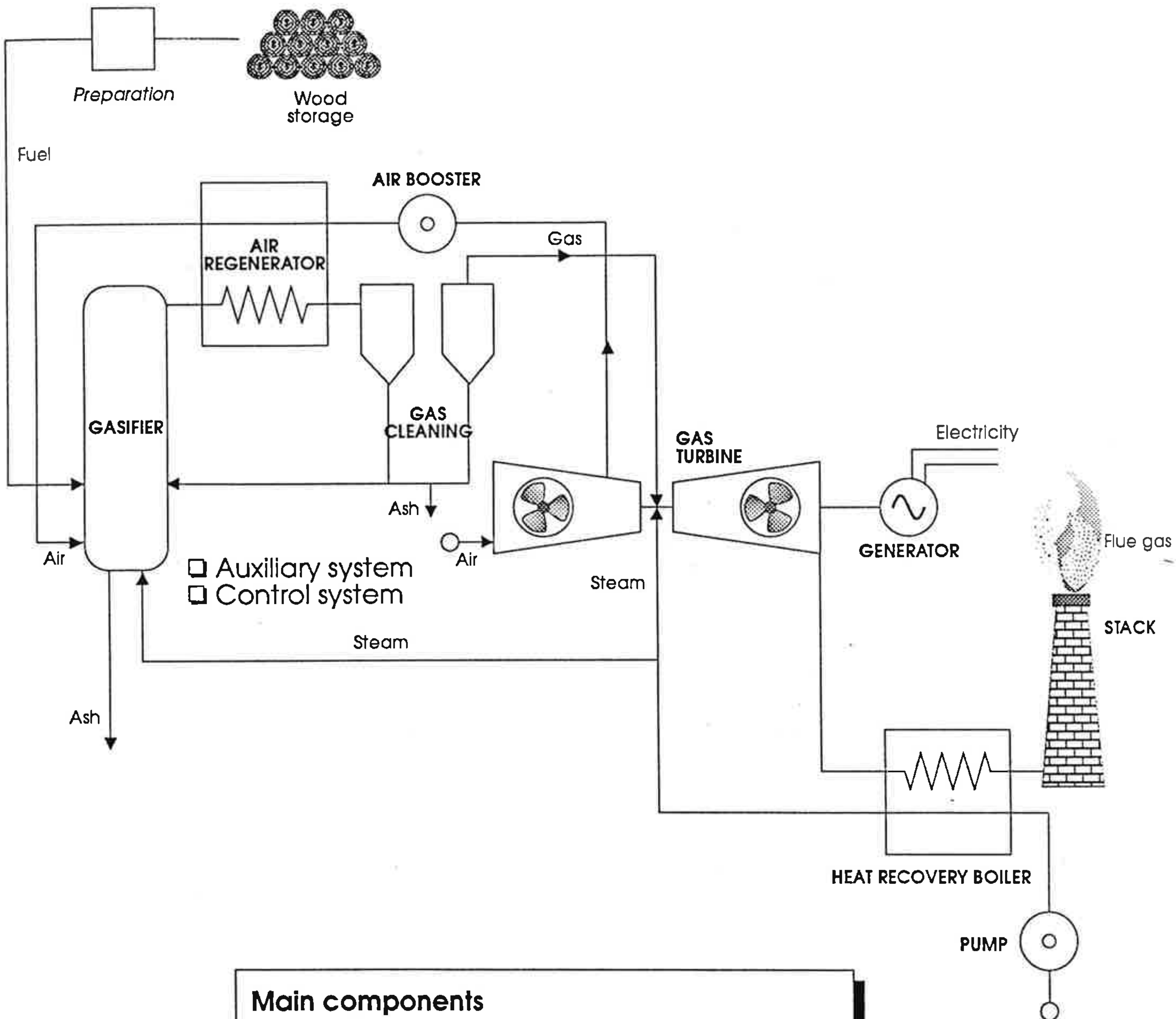
The first three gas turbine cycles are commercially used with distillate or natural gas fuel. The last two are under development. For this reason the focus will be on the first three alternatives for the moment. Figures 4.2, 4.3 and 4.4 show basic cycle diagrams for the three aforementioned gas turbine cycles. Tables 4.3 and 4.4 summarize the data concerning electricity generation for various situations.



Main components

Gasifier	Heat recovery boiler
Gas cleaning	Pumps/piping
Gas turbine	Wood storage
Generator	Wood preparation
Air regenerator	Auxiliary and control systems
Air booster	

Fig 4.2: Biomass gasification · gas turbine open cycle
BIG GTOC



Main components	
Gasifier	Heat recovery boiler
Gas cleaning	Pumps/piping
Gas turbine	Stack
Generator	Wood storage
Air regenerator	Wood preparation
Air booster	Auxiliary and control systems

Fig 4.3: Biomass gasification · steam injected gas turbine cycle BIG STIG

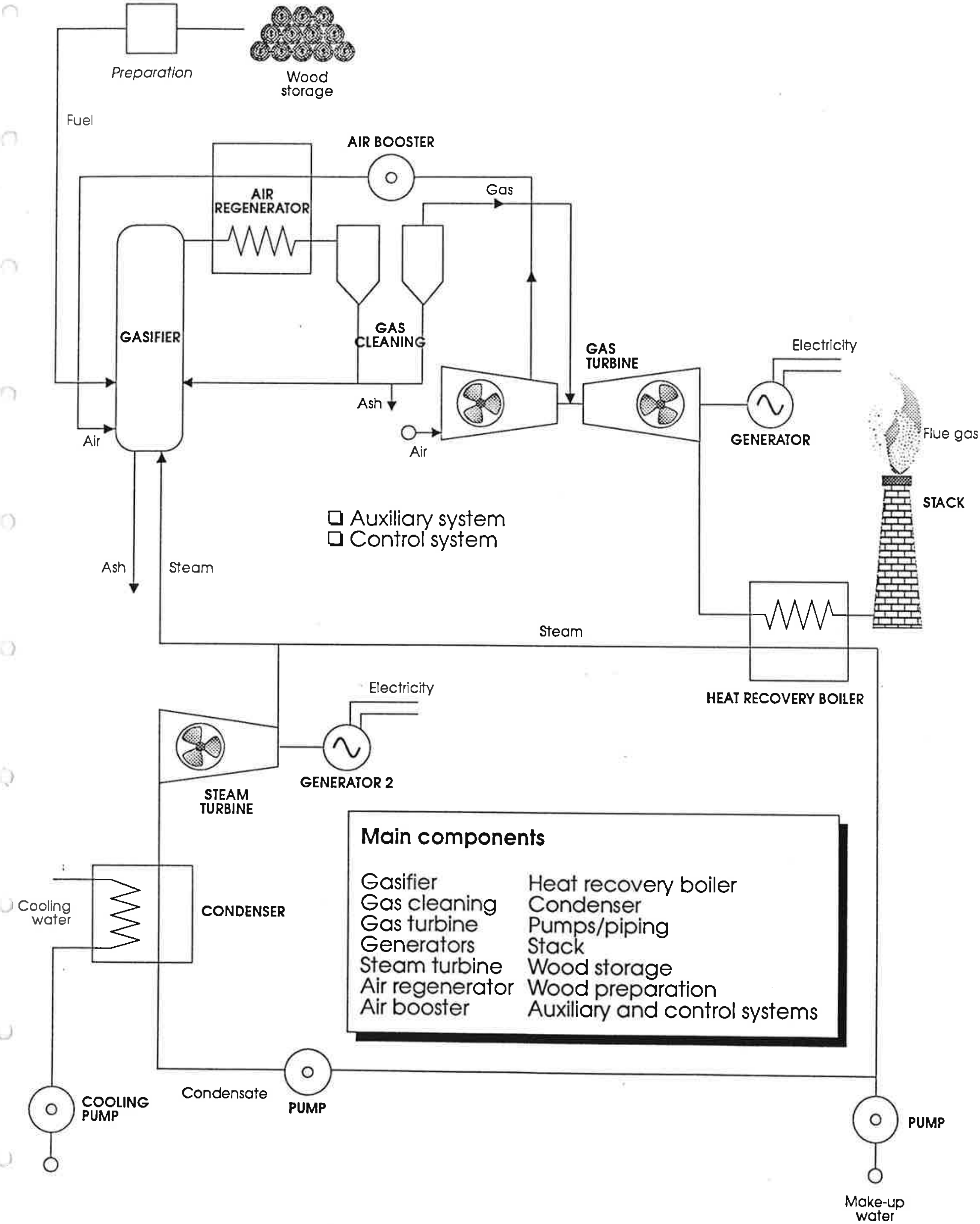


Fig 4.4: Biomass gasification · gas turbine combined cycle
BIG GTCC

TABLE 4.3 GAS TURBINE CYCLE
BIOMASS - SUGAR CANE
ELECTRIC GENERATION PARAMETERS

Required Electricity for Process 15 kWH/t_{sc}

Fuel	Season	Generation Cycle	kwh/t_{sc} Production	Surplus
Bagasse (50% Moist)	On	BIG STIG	225	210*
	Off	BIG STIG	225	225
Tops/Leaves	On	BIG STIG	175	175
	Off	BIG STIG	175	175*
BIOGAS (from stillage)	On	STIG	20.4	20.4*
	Off	STIG	20.4	20.4
	Total Electricity		420.4	405.4*

Remarks: * Most likely operational mode.

TABLE 4.4 GAS TURBINE CYCLES

Biomass - Wood
Electric Generation Parameters

Fuel	Generation Cycle	Net Production kwh/t_w
Wood (33% Moist.)	BIG - GTOC	763
	BIG - STIG	1080
	BIG - GTCC	1233

4.2 ELECTRICITY COSTS

The objective of this section is to assess the costs of electricity produced using the various systems discussed in section 4.1. The analysis will be made for sugar cane and wood from plantations and, as some uncertainty remains about the opportunity cost for bagasse and the actual discount and interest rates to be used for both (sugar cane and wood plantations industry), a sensitivity evaluation will be made instead of studying a particular situation.

4.2.1 ELECTRICITY COSTS - SUGAR CANE

In estimating the cost of electricity produced in sugar mills and distilleries it is important to have in mind the present configuration of existing power generation installations and what is envisaged for the future.

Most of the existing facilities in the sugar industry were designed under the concept that the only use for bagasse would be to raise process steam and to meet the factory or distillery electricity needs. Under this concept, low reliability and efficiency were acceptable. Low cost was a major aim. The actual status of most of the existing installations in Brazil reflects this concept. Further evidence of this is CHESF's actual experience during the period from 1987 to 1989, when around ten sugar cane processing mills were grid connected. It was evident how difficult it was to keep those installations on the grid for long periods.

The necessity of increasing the competitiveness of cane processing in order to survive has been the major push to replace the traditional concept with a new one, where maximum excess bagasse production is among the major aims. This has led to the discovery of new uses for this by-product. Producing electricity has been recognized as one of the best possibilities. It is under this new concept of an "energy industry" that electricity production costs will be analyzed.

Table 4.5 shows the basic parameters used to calculate total electricity costs. Table 4.6 shows the costs for fuel, operation and maintenance, and investment for the CEST and BIG/STIG conversion systems. It is interesting to note that for each technology the fuel costs with or without biogas are in practical terms the same. A great difference between the two technologies is in the investment costs, which results from higher investment per installed kw and lower efficiency for the CEST system. Tables 4.7 and 4.8 show the total cost of electricity for the CEST and BIG/STIG systems. (These tables use fuel costs without biogas, which gives a lower short term value.)

The results indicate clearly the difference in competitiveness that exists between the two systems. They also indicate that unless lower investment costs are forthcoming for CEST, once the BIG/STIG system is commercially available, it will tend to phase out CEST units.

TABLE 4.5 BASIC ASSUMPTIONS TO CALCULATE THE COST OF ELECTRICITY IN THE SUGAR INDUSTRY (SOURCE - CHAPTER 3)

(1) Electricity Production (Surplus)

	kwh/t_c	
Fuel	CEST	BIG - STIG
Bagasse	85	210
Tops & Leaves	11.6	175
Biogas	11.6	20.4
TOTAL	212.6	405.4

(2) Power Plant Capacity - Sugar mills and distilleries

Milling tc/d	1714	3429
CEST Mw	7.20	14.30
BIG-STIG Mw	16.10	32.20

(3) Overall efficiency (LHV)

	%
CEST	16
BIG-STIG	36

(4) Fuel Costs

Bagasse	\$/t_B	0.00 - 40.00
	\$/tc	0.00 - 12.00
Tops & Leaves	\$/tc	2.85
Biogas	\$/tc	0.36

Milling - 1714 tc/d
Biogas Prod. - 15837 Nm^3/d
Install. Life - 20y
Season - 160 d/y
Interest Rate - 10% per y.
Inv. Cost - \$ 572,476.00
O & M Cost - \$/y 30,200.00

TABLE 4.5 (continued)

(5) Operation and Maintenance Costs

	CEST	BIG-STIG
O & M $/mwh	7.5	6.0

(6) Investment Costs

Equipment Life - 25 y
Milling season - 160 d/y
Operation period:
- Bagasse - 160 d/y
- Biogas - 160 d/y
- Tops & Leaves - 80 d/y

Installed cost:	$/kw
CEST	2100
BIG-STIG	1170

TABLE 4.6 SUGAR CANE ELECTRICITY COSTS

Fuel Costs

Bagasse

$/t$_B$	0	5	10	15	20	40
$/tc	0	1.5	3.0	4.5	6.0	12.0
CEST			$/MWh			
w/BIOGAS	15.1	22.1	29.2	36.3	43.5	71.5
w/o BIOGAS	14.2	21.6	29.1	35.4	44.2	73.8
BIG-STIG						
w/BIOGAS	7.8	11.5	15.2	18.9	22.7	37.5
w/o BIOGAS	7.3	11.2	15.1	19.1	23.0	38.8

O/M Costs

	$/MWh
CEST	6.0 - 9.0
BIG-STIG	6.0

Investment costs

		$/MWh	
	10%	15%	20%
CEST	40.1	56.4	73.6
BIG-STIG	22.4	31.4	41.0

Remarks: Bagasse used on season and tops and leaves off season.
Capacity factor 0.658.

TABLE 4.7 SUGAR CANE ELECTRICITY COSTS

CEST

		$/MWh	
Interest Rate %	10	15	20
Invest.	40.1	56.4	73.6
O & M	7.5	7.5	7.5
Invest + O&M	47.6	63.9	81.1

Bag.Cost ($/tc)	Fuel $/MWh	Total Energy Cost		
0	14.2	61.8	78.1	95.3
1.5	21.6	69.2	85.5	102.7
3.0	29.1	76.7	93.0	110.2
4.5	35.4	83.0	99.3	116.5
6.0	44.2	91.8	108.1	125.3
12.0	73.8	121.4	137.7	154.9

TABLE 4.8 SUGAR CANE ELECTRICITY COSTS

BIG - STIG

		$/MWh	
Interest Rate %	10	15	20
Invest.	22.4	31.4	41.0
O & M	6	6	6
Invest + O&M	28.4	37.4	47

Bag.Cost ($/tc)	Fuel $/MWh	Total Energy Cost		
0	7.3	35.7	44.7	54.3
1.5	11.2	39.6	48.6	58.2
3.0	15.1	43.5	52.5	62.1
4.5	19.1	47.5	56.5	66.1
6.0	23.0	51.4	60.4	70.0
12.0	38.8	67.2	76.2	85.8

Assuming the same O&M costs for both systems, the maximum investment cost for CEST to compete would be around $520 per kw. This is the cost of typical installations currently in use in sugar factories. However, existing units cannot achieve the necessary 16% efficiency level.

In other words all evidence suggests that a major push should be made for development of the BIG/STIG system. Table 4.7A and 4.8A show the total cost of electricity if only bagasse is used as fuel only during the willing season.

TABLE 4.7A SUGAR CANE ELECTRICITY COSTS (1988)

CEST w/o T&L

shouldn't be same as w/T&L (p.221)

			$/MWh	
Interest Rate %		10	15	20
Invest.		40.1	56.4	73.6
O & M		7.5	7.5	7.5
Invest + O&M		47.6	63.9	81.1
Bag.Cost	Fuel		Total Energy Cost	
($/tc)	$/MWh			
0	0	47.6	63.9	81.1
1.5	17.6	65.2	81.5	98.7
3.0	35.2	82.8	99.1	116.3
4.5	53.0	100.6	116.9	134.1
6.0	71.0	118.6	134.9	152.1
12.0	141.0	188.6	204.9	222.1

TABLE 4.8A . SUGAR CANE ELECTRICITY COSTS (1988)

BIG - STIG w/o T&L

		$/MWh	
Interest Rate %	10	15	20
Invest.	22.4	31.4	41.0
O & M	6	6	6
Invest + O&M	28.4	37.4	47

Bag.Cost ($/tc)	Fuel $/MWh	Total Energy Cost		
0	0	28.4	37.4	47
1.5	7.1	35.5	44.5	54.1
3.0	14.2	42.6	51.6	61.2
4.5	21/4	49.8	58.8	68.4
6.0	28.6	57.0	66.0	75.6
12.0	57.2	85.6	94.6	104.2

4.2.2 ELECTRICITY COST - WOOD

To estimate the cost of electricity produced using wood from plantations as the prime fuel, yields were assumed to vary from 10 m^3sol/ha.y up to 40 m^3sol/ha.y, which covers most of the cases found in the Northeast of Brazil.

No specific site is considered here. Rather, the idea is to show cost variations according to changes in yields, conversion system and interest rates applied to the capital investment. To calculate the cost of wood a discount rate of 10% was used, which may be considered high for industrialized countries, but is widely used in Brazil, including the electricity power business.

The results are shown in tables 4.9 through 4.14. The first contains the cost of wood per solid cubic meter, per tonne, and per unit of energy, considering a wood moisture content of 33%.

Its value varies between 9.3 \$/m^3sol and 27.7 \$/ m^3sol. For the average yield of the Northeast region (26.2 m^3sol/ha.y), it is in the 10.3 - 17.0 \$/m^3sol range.

Tables 4.10 through 4.13 show the total cost of energy for the various situations. It is clear that the steam cycle does not compete with the gas turbine based alternatives. Disregarding the differences in the O&M costs, to be competitive the steam option would have to have its capital cost around $660 per installed kw, and efficiency would need to be increased by 15% to 20%.

Another conclusion is that the BIG/STIG and BIG/GTCC can produce electricity at costs that are competitive with any other energy source, even hydro.

Finally in table 4.14 are shown the basic assumption or parameters used to evaluate the cost of electricity.

TABLE 4.9 COST OF WOOD (1988)

M^3_{sol}/ha.y	$\$/M^3_{sol}$		$\$/t_w$		$/GJ	
	L	H	L	H	L	H
10	18.2	27.7	25.6	39.0	2.3	3.5
20	12.3	17.0	17.3	23.9	1.6	2.2
30	10.3	13.5	14.5	19.0	1.3	1.7
40	9.3	11.7	13.1	16.5	1.2	1.5

Remarks: Discount Rate 10%

Wood with 33% moist.

Wood density 0.71 t/m^3_{sol}

Wood heat value: 11.1 GJ/t (LHV)

L and H relates to the land and implantation costs

TABLE 4.10 WOOD ELECTRICITY COST (1988)

CST

		$/MWh	
Interest Rate %	10	15	20
Investment	34.6	48.6	63.5
O & M	6.9	6.9	6.9
Invest. + O & M	41.5	55.5	70.4

		Fuel		Total Energy Cost	
M^3_{sol}/ha.y		$/MWh			
10	L	40.0	81.5	95.5	110.4
	H	60.9	102.4	116.4	131.3
20	L	27.0	68.5	82.5	97.4
	H	37.3	78.8	92.8	107.7
30	L	22.7	64.2	78.2	93.1
	H	29.7	71.2	85.2	100.1
40	L	20.5	62.0	76.0	90.9
	H	25.8	67.3	81.3	96.2

TABLE 4.11 WOOD ELECTRICITY COST (1988)

BIG - GTOC

		$/MWh	
Interest rate %	10	15	20
Investment	14.0	19.7	25.7
O & M	4.6	4.6	4.6
Investment + O & M	18.6	24.3	30.3

		Fuel		Total Energy Cost	
m^3_{sol}/ha.y		$/MWh			
10	L	35.4	54.0	59.7	65.7
	H	53.9	72.5	78.2	84.2
20	L	23.9	42.5	48.2	54.2
	H	33.1	51.7	57.4	63.4
30	L	20.1	38.7	44.4	50.4
	H	26.3	44.9	50.6	56.6
40	L	18.1	36.7	42.4	48.4
	H	22.8	41.4	47.1	53.1

TABLE 4.12 WOOD ELECTRICITY COST (1988)

BIG - STIG

		$/MWh	
Interest rate %	10	15	20
Investment	17.3	24.3	31.7
O & M	4.6	4.6	4.6
Investment + O & M	21.9	28.9	36.3

m^3_{sol}/ha.y		Fuel $/MWh	Total Energy Cost		
10	L	23.7	45.6	52.6	60.0
	H	36.1	58.0	65.0	72.4
20	L	16.0	37.9	44.9	52.3
	H	22.1	44.0	51.0	58.4
30	L	13.4	35.3	42.3	49.7
	H	17.6	39.5	46.5	53.9
40	L	12.0	33.9	40.9	48.3
	H	15.3	37.2	44.2	51.6

TABLE 4.13 WOOD ELECTRICITY COST (1988)

BIG - GTCC

		$/MWh	
Interest rate %	10	15	20
Investment	16.5	23.1	30.2
O & M	4.6	4.6	4.6
Investment + O & M	21.1	27.7	34.8

		Fuel		Total Energy Cost	
m^3_{sol}/ha.y		$/MWh			
10	L	20.5	41.6	48.2	55.3
	H	31.6	52.7	59.3	66.4
20	L	14.0	35.1	41.7	48.8
	H	19.4	40.5	47.1	54.2
30	L	11.8	32.9	39.5	46.6
	H	15.4	36.5	43.1	50.2
40	L	10.6	31.7	38.3	45.4
	H	13.4	34.5	41.1	48.2

TABLE 4.14 WOOD ELECTRICITY COST - BASIC ASSUMPTIONS

Fuel Cost

Wood yields 10 - 40 m^3_{sol}/ha.y

Wood moisture 33%

Wood heat value 11.1 GT/t (LHV)

Wood density 0.71 t/m^3sol

Wood	Low(L)	Land	100$/ha
		Implan.	367 $/ha
	High(H)	Land	300 $/ha
		Implant.	811 $/ha

Discount rate 10% a y.
Wood productive cycle 18y
3 cuts
6 y/cut

Operation and maintenance costs

CST 6.9 $/mwh

BIG GTOC
STIG 4.9 $/mwh
GTCC

Investment cost

Equipment life 25y
Capacity factor 0.85
Interest rates 10% - 20%

Invest. cost		$/kw
CST		2341.00
BIG	GTOC	947.00
	STIG	1170.00
	GTCC	1113.00

Equipment characteristics

		Size Mw	Units	Eff. %	MWh/tw
	CST	50	(2 x 25)	21	0.640
BIG-	GTOC	60	(3 x 20)	25	0.723
	STIG	60	(2 x 30)	35	1.080
	GTCC	60	(2 x 20) + (1 x 20)	40	1.233

4.3 MAN POWER REQUIREMENTS (SUMMARY)

In chapter 3 the man power requirements data for the sugar cane and wood plantations industries were shown but no analyses were made. In this section the aim is to evaluate this information and also to try, on a preliminary basis, to qualify the manpower employed in these two areas.

For the sugar cane industry the analysis will be made considering only the present and near future situations and although the analysis will focus in the Northeast, average numbers for the country will be used.

4.3.1 SUGAR CANE MAN POWER REQUIREMENTS

Table 4.15 shows the manpower requirements. It is a summary of the information in tables 3.22 and 3.23.

The comparison and analysis of its figures lead to some interesting conclusions:

(a) The comparison of the annual and seasonal manpower requirements shows very clearly why there are so many lay offs in the sugar cane industry in the off-season period. The industry needs during the season are almost twice as high as in the off season, 0.171 M/ha as compared to 0.096 M/ha.

(b) If a decision is made to use the tops and leaves the following situations would appear.
   - If it is used for electricity on-season, it would only worsen the present situation, increasing the difference between the on and off season man power requirements.
   - Baling on-season would be the worst case from an employment standpoint, as the baling manpower requirements are comparable to the agricultural needs.

- Used without baling, Tops and leaves for off-season electricity production would ease the employment situation, but on a small scale.
- Off-season baling for electricity generation or other purposes, on the other hand, could essentially solve the industry off-season layoff problem, as the on season man power requirements for standard industry operations almost matches the annual requirements when the baling activity is added. (0.196 M/ha as compared to 0.182 M/ha.)

(c) Considering the aforementioned, it seems that the best option, from the electricity generation standpoint, would be to:
- stop burning the sugar cane before harvesting.
- gather the tops and leaves and stock them in small piles as a parallel activity to the cane harvesting.
- leave them in the fields for a period of three to four months. This activity must be carefully planned as it should not interfere or damage the new sprouts.
- start baling after this period and use the bales as fuel for electricity production.
- this set of actions would maximize the value of electricity sold by the sugar cane industry. Its generation could be much more easily incorporated, in the overall electricity generation planning, for the whole region. In other words, it would be easier to integrate this new generation capacity into the existing system, with maximum social benefits. base load

In table 4.16 it is shown what would appear to be the actual man power qualification distribution throughout the sugar cane industry. It must be taken as a preliminary approach, however, as the information assessed was rather scarce.

It is important to have in mind that, although these constraints are real and could mean there are actually variations in the figures shown in table 4.16, the range in which the three qualification levels are placed should not change. In other words, one cannot expect to have 20% to 30% of high qualification personnel being employed in the sugar industry, no matter how accurate is the available information.

These figures show that to get higher living standards, attention should be focused over the low income, low qualification personnel and relate it to productivity gains, in order to maintain or increase competitiveness.

It seems clear that the above policy can go on up to a certain point, when mechanization will have to be introduced to raise living standards.

So, if these conclusions are proven right one should look for the turning point as soon and precisely as possible to anticipate actions aiming to soften the transition between the two phases.

TABLE 4.15 SUGAR CANE MAN POWER REQUIREMENTS

Phase	Seasonal (M/ha) Present	Seasonal (M/ha) Near future	Annual (M/ha) Present	Annual (M/ha) Near future	
Agricultural	0.153	0.153	0.086	0.086	
Transportation	0.018	0.018	0.010	0.010	
Processing	0.027	0.025	0.027	0.029	
Subtotal	0.198	0.196	0.123	0.121	
T&L Baling	-	0.108	-	0.061	
T&L Electricity	-	0.014	-	0.008	
TOTAL	0.198	0.304	0.123	0.182	T&L Baling or off season electr. prod.
		0.210		0.129	T&L on season

Remarks: It is assumed that for off season electricity production the top and leaves should be baled.

from where?

.025?

TABLE 4.16 SUGAR CANE MAN POWER QUALIFICATIONS

Qualif. Level	Agricult. & Transport (%)	Process. (%)
High	2	5
Medium	4	8
Low	94	87

Remarks:

High: manager, engineers, and top administrative

Medium: technicians, operators, group supervisors and skilled laborers.

Low: unskilled laborers.

4.3.2 WOOD PLANTATION MANPOWER REQUIREMENTS

For actual and future foreseen wood plantation activities, the situation is quite different from sugar cane and appears to be simpler. The reason relates directly to the fact that it is an annual culture, or multi-annual, based on the usual current pattern of activities observed for most of the economic, commercial or industrial activities.

As compared to sugar cane, it is a much newer agroindustry, which already has a more balanced scope between manual and mechanized activities. Tables 4.17 and 4.18 contain the data for manpower requirements and its qualification, which are quite similar to those for sugar cane, but, regarding the requirements of manpower, it is between 4 and 6 times less intensive, which reflects the differences between the two cultures, besides the level of mechanization achieved in each case.

It is interesting to note that not only in the agricultural phase, but even in the processing, which corresponds to the conversion phase for wood, the sugar industry requires about 7 to 8 times more personnel. This may reflect a lower level of automation which in turn may mean lower investment costs. This fact could explain some of the differences between the capital costs for sugar mills and refineries in Brazil and other parts of the world. (Capital costs in Brazil are about half that of U.S.) (Ref. 14 chapter 3).

Regarding the qualifications of the personnel, although the availability and quality of information is better than for sugar cane, some degree of inaccuracy still persists.

TABLE 4.17 WOOD PLANTATIONS FOR ELECTRICITY; MANPOWER REQUIREMENTS

M/ha

Phase	Conversion	Agricultural	Total
Fuel Product.		0.0274	0.0274
Electr. Product.			
CST	0.0069		0.0343
BIG GTOC	0.0034		0.0308
STIG	0.0035		0.0309
GTCC	0.0039		0.0313

Remarks:

High: manager, engineers, and top administrative

Medium: technicians, operators, group supervisors and skilled laborers.

Low: unskilled laborers.

TABLE 4.18 WOOD PLANTATIONS FOR ELECTRICITY; MANPOWER QUALIFICATIONS

	%	
Qualification Level	Agricultural	Conversion
High	2 - 3	5 - 8
Medium	6 - 8	8 - 10
Low	89 - 92	82 - 87

Remarks:

High: manager, engineers, and top administrative

Medium: technicians, operators, group supervisors and skilled laborers.

Low: unskilled laborers.

4.4 INITIAL APPROACH TO MODELS FOR BIOMASS ELECTRICITY DEVELOPMENT

This section aims to present some initial ideas about a model for how the development of a biomass for electricity industry might proceed. Given the broadness and multitude of aspects comprised by this issue and its linkage with time and happenings in this and other areas, it would be useless to try to focus on every aspect. However, some basic points which can be considered as cornerstones for the success of the basic idea are raised and discussed.

The area of concern relates more to the production and use of wood from plantations than to sugar cane. The main reason for this is that for sugar cane a well established industry already exists. The more efficient use of energy or the use of a new generation of technology is more a question of evolution than in the case of wood electricity, where it is necessary to start a new industrial segment. With sugar cane the major innovation would be to begin using the tops and leaves that presently are burned or left on the field. This would require stopping the pre-harvest burns and would certainly lead to more efficient use of energy in the industry and to the incorporation of better steam power technologies.

Another fact that is likely to occur is a continuous upgrading of the existing installations, rather than brusk changes toward more efficient systems. It is important to have in mind that the next generation technology, gasification-gas turbines, still has some five years to go until a full commercial stage is achieved and probably three to five additional years before it can be considered completely absorbed.

So for sugar cane, it seems that the best course to follow would be to take immediate action to improve today's situation and at least keep closely informed on the progress of the gasification gas turbine technology. A more active course could be taken if a decision is made within the sugar industry to participate in the development of the new technology.

Regarding the use of wood, the situation is a little more complicated as power generation would be a new development. Nowadays there exists in Brazil large entrepreneurial wood plantations associated with charcoal for steel and with pulp and paper industries. Although large and well managed, these plantations are connected to their parent companies and their needs. So in general they are under full control of the main industry, and its size is dictated by the size of the operations of the controller.

The linkage between wood plantations and electricity production is something different in the sense that electricity is a fundamental service needed to improve living standards and there is a natural tendency to spread its use. It is also related to a number of other factors, including population growth, educational level, present level of consumption, stage of achieved economic development and to actual economic activities. All this points in the direction of a much less direct control of the size of operations that could be involved. Adding to these facts lies the basic idea that the use of biomass should provide not only electricity or energy but also a hard push on social development.

If it is to be so, a fundamental aspect that will influence the success of this strategy is the way that land necessary to grow trees will be provided. It is vital to realize that the use of land remains as one of the major unresolved issues in Brazil. With this in mind, it is easy to understand how carefully the land issue must be approached.

To be competitive the biomass for electricity alternative must rely on:

- affordable cost of land; skyrocketing land prices will just kill off all possibilities of success
- advanced silviculture technology to get the best possible yields
- sound long term economic and financial basis
- social acceptance

A preliminary appraoch to a first model intended to cover all these aspects should rely on:

- renting or leasing of land and just minimally on buying
- maximum incentive for land owners to participate, preferably in association with entrepreneurial third parties and/or cooperatives
- before getting started with a program aiming for large scale results, a sound technical basis must be implemented to support and guarantee the commercial results
- any program must rely on long term contracts which will assure continuation of the business
- a permanent monitoring of the programs results by universities and research institutes should be incorporated
- open discussion of the programs' aims and consequences is fully necessary
- maximum integration of local communities; where a project is being developed is of fundamental importance
- finally, permanent political support is necessary, in such way that long-term decisions prevail over short-term interests and sound supporting policies are established.

4.5 BIOMASS ELECTRIC GENERATION POTENTIAL IN NORTHEAST BRAZIL

To evaluate the amount of electricity that potentially could be produced in Northeast Brazil using biomass two different methodologies were used. The first applied to sugar cane is based on the maximum sugar cane production already achieved in each state. From this basic data the possible amount of electricity production was calculated for the CEST/CST and BIG/STIG technologies, and in each case for three different situations: using only bagasse, bagasse plus tops and leaves and finally bagasse, tops and leaves and biogas from stillage.

The results are shown in Table 4-19. They make clear the differences between the two technologies and the effect of using the sugar cane tops and leaves, which in some cases doubles the electricity produced per tonne of sugar cane. The results shown in Table 4-19 also make clear that in any case the amount of energy that can be produced in the sugar cane industry is significant.

For wood plantations another approach was used. As a first step a summary of the characteristics of each bioclimatic region existing in each Northeast state was made (see Appendix A-4), and an area distribution per bioclimatic region was prepared (Table 4-20). From this point, and using the annual precipitation as a linkage factor between these areas and the yield data developed in Chapter 3, characteristic Eucalyptus yields for each bioclimatic region were defined (see Table 4-21). The next step was to calculate the potential wood production for each state (see Table 4-22). Finally the potential electricity production was calculated for each of the four conversion technologies in (Table 4-23).

TABLE 4-19 SUGAR CANE POTENTIAL FOR ELECTRICITY PRODUCTION IN NORTHEAST BRAZIL

State	Highest Achieved Sugar Cane Production t_{sc}(4)	Season	Gwh/y CEST/CST Bagasse	Bagasse + T & L	Bagasse + T & L Biogas	BIG-STIG Bagasse	Bagasse + T & L	Bagasse + T & L Biogas
MA	779531	86/87	66.26	156.69	165.73	163.70	300.12	316.02
PI	263733	86/87	22.42	53.01	56.07	55.38	101.54	106.92
CE	795170	87/88	67.59	159.83	169.05	166.99	306.14	322.36
RN	3578336	86/87	304.16	719.25	760.75	751.45	1377.66	1450.66
Pb	6172050	86/87	524.62	1240.58	1312.18	1296.13	2376.24	2502.15
Pe	25794180	86/87	2192.51	5184.63	5483.84	5416.78	9930.76	10456.96
Al	30262601	86/87	2572.32	6082.78	6433.83	6355.15	11651.10	12268.46
Se	2131300	86/87	181.16	453.11	428.39	447.57	820.55	864.03
Ba	1435327	86/87	122.00	305.15	301.15	301.42	552.6	581.88
	71,212,228	Total	6053.04	14313.67	15139.71	14954.57	27416.71	28869.44
	MW_a (MW y/y)		691	1634	1728	1707	3130	3296
	Install Cap. MW		1051	2485	2628	2596	4760	5013

TABLE 4-19 REMARKS

(1) To calculate the potential electricity production, cane production was assumed to be the highest registered historically by the industry.

(2) The net eletricity production rates for the CEST/EST and BIG/STIG conversion systems are those shown in Tables 4-1 and 4-3.

(3) It was assumed that bagasse and biogas would be used on season and tops and leaves off season. Bagasse with 50% moist.

(4) The maximum capacity factor used to calculate the installed capacity was 0.658 which results from 160 days of on-season operation plus 80 days of-off season electricity production with tops and leaves.

The conclusions are that the amount of energy is very large -- comparable to the regional hydro resources for sugar cane and to the entire country's hydro resources for wood. The use of the gasification gas turbine technology permits a substantial increase in energy production over conventional technology.

As the total electricity potential, shown in Table 4-23, was calculated using all the land suitable for forestry purposes in the Northeast, amounting to about 33% of the Northeast area, it is clear that its full realization would most likely not occur. Thus, Table 4-24 shows results assuming only 5% of the potential land is used in each state. Even in this case, where a total area of approximately 7.72 million ha would be used for forests, the amount of energy that can be produced remains impressive and can reach betwen 17% and 20% of the country hydro potential.

TABLE 4-20 AREA DISTRIBUTION SUITABLE FOR WOOD PLANTATIONS PER BIOCLIMATIC REGION IN NORTHEAST BRAZIL (km^2)

Bioclimatic Region – Defined @ A-4-1.18

State	1	2	3	4	5	Total
MA	32326	33959	95331	410		162,026
Pi			75848	65273		141,121
Ce	623	802	3028	4991		9,444
RN		400	1105	2206	894	4605
Pb	11	1613	1721	1716		5061
Pe	1375	1075	2147	3187	3416	11,200
Al	316	3175	1261	209	20	4981
Se			3838	35		3873
Ba	5891	36355	75106	37607	7319	162,278
Total	40542	77379	259385	115634	11649	504,589

TABLE 4-21 REPRESENTATIVE YIELD PER BIOCLIMATIC REGION

Yield m^3sol of /ha.y

Bioclimatic Region	Precip. mm/y	Average precip. mm/y	Trials Yields	T_a Average yields	T_{corr} Corrected yield (0.7)	Plantations Yields	P_a Yields Average Plantation	Assumed Yields
1	1500-2300	1900	59.9	59.9	45	44	44	44
2	1000-1700	1350	46.9; 45.2 54.5; 30.5	44.3	33	30; 40	35	33
3	700-1300	1000	32.4; 89.3* 48.5	40.3	30	21.1; 30; 31.8	27.6	28
4	500-1000	750	21.9; 5.9*; 18.3	20.1	15	14.7	14.7	15
5	300-600	450	4.7; 24.6* 11.2	8.0	6			6

Remarks: * excluded yields:
89.3 m^3 sol/ha.y
5.9 m^3 sol/ha.y
24.6 m^3 sol/ha.y

TABLE 4-22 NORTHEAST BRAZIL POTENTIAL WOOD PRODUCTION

10^6 m^3 sol/Y

divide by area s (Table 4-20) to get average

Bioclimatic Region / State	1	2	3	4	5	Total
MA	142.23	112.06	266.93	0.62		521.84
Pi			212.37	97.91		310.28
Ce	2.74	2.65	8.48	7.49		21.36
RN		1.32	3.09	3.31	0.54	8.26
Pb	0.05	5.32	4.82	2.57		12.76
Pe	6.05	3.55	60.1	4.78	2.05	22.44
AP	1.39	10.48	3.53	0.31	0.01	15.72
Se			10.75	0.05		10.80
Ba	25.92	119.97	210.30	56.41	4.39	416.99
Total	178.38	255.35	726.28	173.45	6.99	1340.45

TABLE 4-23 WOOD PLANTATIONS POTENTIAL FOR ELECTRICITY PRODUCTION IN NORTHEAST BRAZIL

	Potential Wood Product		Twh/y			
State	10^6 m^3 sol/y	10^6 tw/y	CST	BIG GTOC	BIG STIG	BIG STCC
MA	521.84	370.51	237.13	282.70	400.15	456.84
Pi	310.28	220.30	140.99	168.09	237.92	271.63
Ce	21.36	15.17	9.71	11.57	16.38	18.70
RN	8.26	5.86	3.75	4.47	6.33	7.23
Pb	12.76	9.06	5.80	6.91	9.78	11.17
Pe	22.44	15.93	10.20	12.15	17.20	19.64
Al	15.72	11.16	7.14	8.52	12.05	13.76
Se	10.80	7.67	4.91	5.85	8.28	9.46
Ba	416.99	296.06	189.48	225.89	319.74	365.47
Total	1340.45	951.72	609.10	726.16	1027.86	1173.47
		GW (GW. y/y)	69.53	82.89	117.34	133.96

Remark: wood with 33% moisture

TABLE 4-24 WOOD PLANTATIONS POTENTIAL FOR ELECTRICITY PRODUCTION IN NORTHEAST BRAZIL USING NO MORE THAN 5% OF EACH STATE AREA

State	Potential Wood Product. 10^6 m^3 sol/y	10^6 tw/y	Twh/y CST	BIG GTOC	BIG STIG	BIG GTCC
MA	52.2	37.1	23.7	28.3	40.0	45.7
Pi	27.9	19.8	12.7	15.1	21.4	24.4
Ce	17.1	12.1	7.8	9.3	13.1	15.0
RN	4.7	3.3	2.1	2.5	3.6	4.1
Pb	7.0	5.0	3.2	3.8	5.4	6.1
Pe	9.9	7.0	4.5	5.3	7.6	8.6
AP	4.4	3.1	2.0	2.4	3.4	3.9
Se	3.0	2.1	1.4	1.6	2.3	2.6
Ba	70.9	50.3	32.2	38.4	54.4	62.1
Total	197.1	139.8	89.6	106.7	151.2	172.5
		GW (GW y/y)	10.2	12.2	17.3	19.7

Remark: wood with 33% moisture

Finally it is interesting to have an initial idea of the average cost of electricity from wood for the whole region and also a cost ranking among the states. To get this informations the cost of wood for each bioclimatic region was calculated taking into account the costs, yeilds and conversion systems. A summary of these data are shown in Table 4-25. It was assumed that no wood would be produced in the bioclimatic region 5.

Table 4-26 shows the basic parameters used to calculate the average electricity cost, which amounted to US$ 38.80 per MWh. This number confirms the high potential competitiveness of this electric generation alternative, as compared with any other, even hydro. It is important to remember that this cost is an average over all potential generation. (It is valid for both options presented in Tables 4-23 and 4-24, as the same percentage of area per bioclimatic region was used in both cases). It will vary with time as a function of the percentage of the potential realized and of the cost of the developed areas. An idea of this fact is shown in Table 4-27 which contains the cost of electricity from wood for each state and a cost ranking among them.

In this rank, Alagoas has the lowest cost, followed by Maranhos. Pernambuco, Paraiba, and Bahia come just after with about the same costs. These five states should be the first states considered in launching a wood for electricity program. It is important to have in mind that, although the best information available was used to get to the aforementioned conclusions, these are initial estimates which surely require further detailed and specific investigation.

TABLE 4-25 AVERAGE COST OF ELECTRICITY FROM BIOMASS IN NORTHEAST BRAZIL - BASIC PARAMETERS

Bioclimatic Region	m^3 sol/ha.y	Conversion System	$/MWh
1	44	BIG GTCC	32.7
2	33	BIG GTCC	34.2
3	28	BIG GTCC BIG GTOC	39.1*
4	15	BIG GTOC	55.2
5	6		

Remarks: * Average between BIG GTCC and BIG GTOC energy costs

TABLE 4-26 OVERALL COST OF ELECTRICITY PRODUCED FROM WOOD IN NORTHEAST BRAZIL

Bioclimatic Region	Potential wood product 10^6 m^3 sol/y	Potential wood product 10^6 tw/y	Conversion system	10^6 MWh/y	$/MWh	Total cost 10^6 $/y
1	178.38	126.6	BIG GTCC	156.1	32.7	5104.5
2	255.35	181.3	BIG GTCC	223.5	34.2	7985.7
3	726.28	515.7	BIG GTCC BIG GTOC	596.7	39.1	23331.0
4	173.45	123.1	BIG GTOC	89.0	55.2	4912.8
5	---	---	---	---	--	
TOTAL	1333.5	946.7		1065.3		41334.0

Average cost $/MWh = 38.8

Remarks: Bioclimatic region 5 not accounted - wood 33% moist
Electric Product. BIG GTCC 1.233 MWh/tm
BIG GTCC/GTPC 1.157 MWh/tm
BIG GTOC 0.723 MWh/tm

TABLE 4-27 COST OF ELECTRICITY FROM WOOD IN NORTHEAST BRAZIL PER STATE

State	10^6 MWh/y	10^6 \$/y	\$/MWh	Cost Ranking
MA	442.20	16018.00	36.22	2
Pi	224.70	9595.90	42.71	8
Ce	15.40	640.80	41.61	7
RN	5.40	232.50	43.06	9
Pb	9.95	387.40	38.93	5
Pe	15.90	609.00	38.30	3
Al	13.53	476.40	35.21	1
Se	8.83	34.68	39.28	6
Ba	329.50	12683.80	38.49	4

4.6 BIOMASS AGROINDUSTRIES TYPICAL INCOME DISTRIBUTION

An important aspect of any economic activity is the distribution of the resulting income (revenue), as this gives a fairly good idea of the manpower participation throughout the productive cycle and also serves as a measuring stick for the capital intensity of a particular industrial sector, permitting comparisons among different industrial activities. To have an understanding of the significance of the pararmeters that are shown in the following tables it is important to have a clear idea of how these numbers were built and their limititations. For this study the limits are drawn at the boundaries of the main activity, which means that only the manpower directly connected with it has been counted. The manpower included in the production costs of fertilizers, pesticides, herbicides, equipment bought from third parties, etc, is not included in the parameters shown in the next tables. For the sugar cane agroindustry manpower used in the following operations were taken into account:

Agricultural phase:	Agricultural operations for implanting, maintenance and harvesting
	Manpower services from third parties
	Technical assistance
	Administrative manpower
	Transport manpower
Processing phase:	Direct and indirect manpower services used for processing
	Transport manpower
	Administrative manpower

Table 4-28 shows the percentage of the sugar industry income directed to manpower, as of 1983, in various regions of Brazil for the agricultural and processing phases. It also shows percentages of sugar cane production.

In Table 4-29 is found the absolute percentages of income direct to manpower for the same regions and for the country, as a whole. It can be seen that the manpower participation varies between 32.3% in the state of Goias up to 40.2 in Sao Paulo, with the country average being about 38% which matches with the ratio wages/GNP for Brazil in 1980 as seen in Fig. 4-5.

Figure 4-5 also shows the sugar cane agroindustry income distribution as quoted by Copersucar (2). Although not completely sure it is being assumed that the Copersucar numbers are related to 1987/88 and to its area of operation, the state of Sao Paulo. If true, the comparison of the numbers from these different information sources, even considering their inherent uncertainties, indicates an increasing participation of the labor on the sugar cane agroindustry revenues.

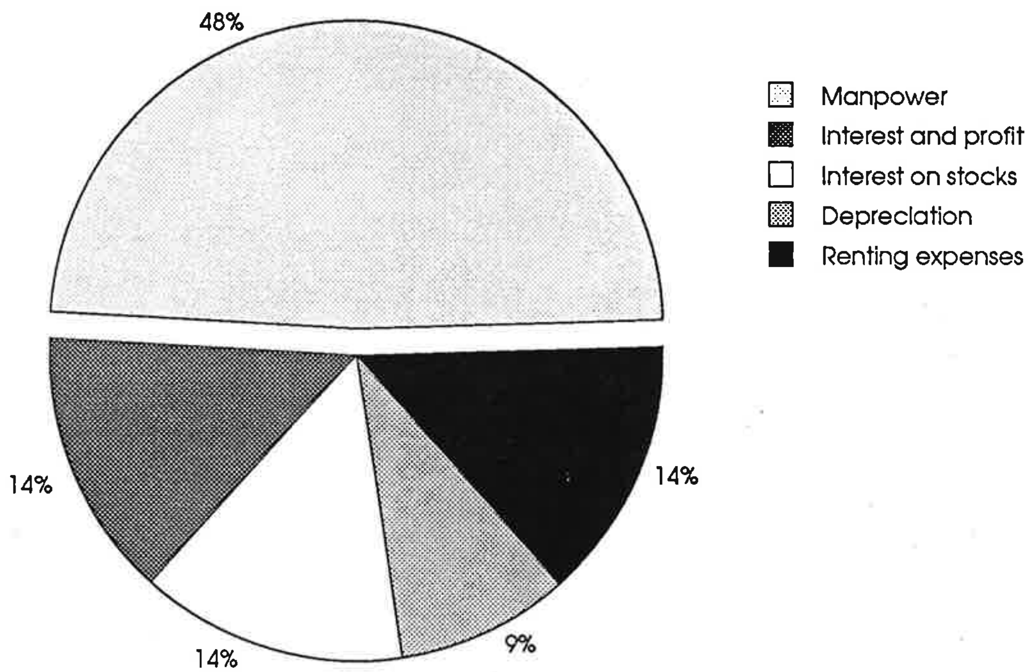


Fig 4.5: Wages/GNP cf · Brazil · 1980 : 38%
Source: Copersucar/FGV

TABLE 4-28 INCOME DISTRIBUTION MANPOWER (3)
(1983)

Agricultural Phase	N/Ne	SP	MG	Pr	GO
Manpower wages (% of ag. phase cost)	44	47	44	48	40
Agricult. costs (% of total costs)	71	72	61	59	69
Processing phase					
Manpower wages (% of proc. phase cost)	13	23	22	18	15
Process costs (% of total costs)	29	28	39	41	31
Sugar cane (% of Brazil production)	32.3	52	4.7	4.9	2.2

TABLE 4-29 INCOME DISTRIBUTION
TOTAL MANPOER PARTICIPATION (% OF TOTAL COSTS)

Phase	N/Ne	SP	MG	PR	GO	BR
Agricult.	31.2	33.8	26.8	28.3	27.6	32.3
Process	3.8	6.4	8.6	7.4	4.7	5.6
Manpower	35	40.2	35.4	35.7	32.3	37.9

Manpower total of sugar cane income: 38% (1983)

Source (3)

For wood produced from plantations, the same course of action was taken to approach the issue of evaluating the manpower share of the total wood cost, which is assumed to be approximately the same as the income distribution. As in the case of sugar cane, an attempt was made to figure out on a percentage basis all the expenses related to the use of human resources in each phase of the wood production cycle. Basically two information sources were used, the CHESF study "Estudos de Reflorestamento no Semiarido Nordestino" (5) (Reforesting studies for the Semi Arid in Northeast Brazil), and a study about wood costs in the state of Minas Gerais made by the University of Vicosa (MG) (6). Tables 4-30 and 4-31 show the results obtained using the data from the aforementioned sources. Table 4-32 is a comparison between them. The main differences are in the manpower share for the growing and administrative plus R&D costs, the other items being quite similar. As this information should be regarded as an inital approach, further effort will be required to improve the informationquality.

TABLE 4-30 WOOD PRODUCTION MANPOWER COST SHARE (5)

(%)

Phase	MP Cost / Phase Cost	Phase Cost / Total Cost	MP Cost / Total Cost
Implant.	15.9	33.6	5.34
Growing	71.1	10.4	7.40
Harvesting & Transp. (60 km)	25.0	54.5	13.63
Adm *	100	1.5	1.5
Red	100	2.7	2.7
			30.17

Manpower 30.2%

Remarks: * Adm cost from ref. (5) were corrected using the same correction factors used in Chapter 3

COSTS

Correction Factors: Implantation 1/5 Growing 1/50

TABLE 4-31 MANPOWER SHARE OF THE TOTAL COST OF WOOD PRODUCTION (6)

(%)

Phase	MP cost / Phase cost	Phase cost / Total cost	MP cost / Total cost
Implanting	53	14.6	7.74
Growing			
Maint.	84.5	12.7	10.73
Regenerat.	80.9	3.4	2.75
Harvesting & Transp. (50km)	27.8	47.1	13.10
Adm. & Red	70*	15	10.5
			44.8

Remarks: * Assumed based on other information sources

TABLE 4-32 WOOD PRODUCTION MANPOWER COST SHARE

SUMMARY

Manpower cost/total wood cost - (%)

Phase	Ref. (5)	Ref. (6)	Average
Implant.	5.34	7.74	6.54
Growing	7.40	13.48	10.44
Harv. & Transp.	13.63	13.10	13.37
Adm. & Red	4.2	10.5	7.35
	30.2	44.8	37.7

4.7 REGIONAL IMPACT OF BIOMASS ELECTRICITY: AN INITIAL APPROACH

The main idea of this section is to shed some light on the real possibilities of developing biomass electricity in a certain time frame, its requirements and possible repercussions. As in prior sections the focus will be on the use of sugar cane residues and wood from plantations, both of which will be analyzed from time, investment, employment and electricity production stand points. It is important to have in mind that an accurate analysis would only be possible with a precise operational simulation of the Northeast and North electric systems, which is beyond the scope of this study. The intention here is only to show a preliminary analysis of what would be reasonable to expect from the development of biomass electricity on a broad basis in Northeast Brazil.

The analysis will be based on the following assumptions:

(a) The Northeast region has a guaranteed supply of electricity from hydro resources up to the years 1998 to 2000.

(b) The CEST technology is available and can be used immediately.

(c) The biomass gasification/gas turbine technology requires some degree of development to be demonstrated on a commercial basis, which is judged to take about 5 to 7 years.

(d) In both cases the human resources (manpower) necessary to run the new plants will have to be trained.

(e) The large, government owned, Brazilian utilities (Eletrobras System) will be operating under severe economic restrictions, at least for the next 5 years.

(f) The seriousness of the situation will be understood by country policy makers, leading to a more sound and realistic tariff policy designed not only for immediate results, but also long-term benefits.

4.7.1 ANALYSIS FROM THE CHRONOLOGICAL STANDPOINT

Figures 4-6 and 4-7 show the time table for the development of the CEST conversion system for the sugar cane industry and of BIG GT conversion systems that can be used for both sugar cane residues and wood. These time schedules were made based on the following assumptions.

CEST SYSTEM

(a) A tariff policy would be established within one year.

(b) The sugar cane residue potential for electricity would be gradually developed in the timeframe shown in Fig. 4-6 item 2.

(c) The erection of the new power plants would take about 3 years.

(d) A decision would be made to use tops and leaves as off season fuel.

(e) The maximum potential development would be of the order of 85% of the total.

BIG-GT SYSTEM

(a) Getting started with a demonstration project would take between one and two years.

(b) Its engineering and erection would take around 3 years and about the same time would be necessary for set up and test operation

(c) Commercial project engineering would begin 2 years after the operation of the demonstration power plant.

Accepting as reasonable these assumptions, the following conclusions can be drawn from the comparision of the information in Fig 4-6 and 4-7.

(a) Although some preliminary results on electricity production could be gotten from the existing installations, a substantive increase in production from CEST plants would only begin in the third year after the tariff policy was settled.

(2) With a 7 year period to have the sugar cane residue potential fully developed, it would happen 9 years after the existence of a tariff policy, or around the year 2001.

(3) The full development of the sugar cane residue, under the assumptions made, would represent an additional 1475 Mwy/y for the CHESF system, or approximately 50% (half) of the XINGO hydropower plant. Xingo is planned for comissioning by the end of 1994, 1995 would be its first operational year, and a 4 year

period to have its output fully used (CHESF estimates that it will happen in no more than 2.5 years). This means that by the end of 1998 it would be necessary to add new capacity to the system. The use of bagasse, under the assumptions made in this study, could supply power for approximately two more years (increases of around 750 MWh/y).

(4) A decision to use the BIG GT system would postpone the beginning of an efficient use of the sugar cane residues for at least 4.5 years most probably between 5 and 6 years.

(5) The use of electricity from plantations cannot be expected before 1999, even if a decision to implement a demonstration project were made within a year from now (Feb/91).

(6) The use of international experience will not make a great difference, since no more than a year may expected to be gained. On the other hand, a decision to start commerical plantations would have to be made in no more than one year, probably 6 months, and more important, the level of knowledge and experience gained by the country would be incomparably lower.

(7) The postponement of increased electricity production in the sugar cane industry caused by a decision to use BIG-GT systems may be offset by its higher efficiency, which enables the production of twice as much electricity as the CEST system, reaching comparably CEST energy production levels in half of the time and mainly by the fact that at the probable time of introduction of the BIG GT system, the first CEST installations will have an average age of 5 years, or 20% of its lifetime.

All this indicates that from the chronological standpoint the best course of action would be to improve the existing sugar cane industry power installations, and join the necessary efforts to have a strong push for the BIG/GT system development.

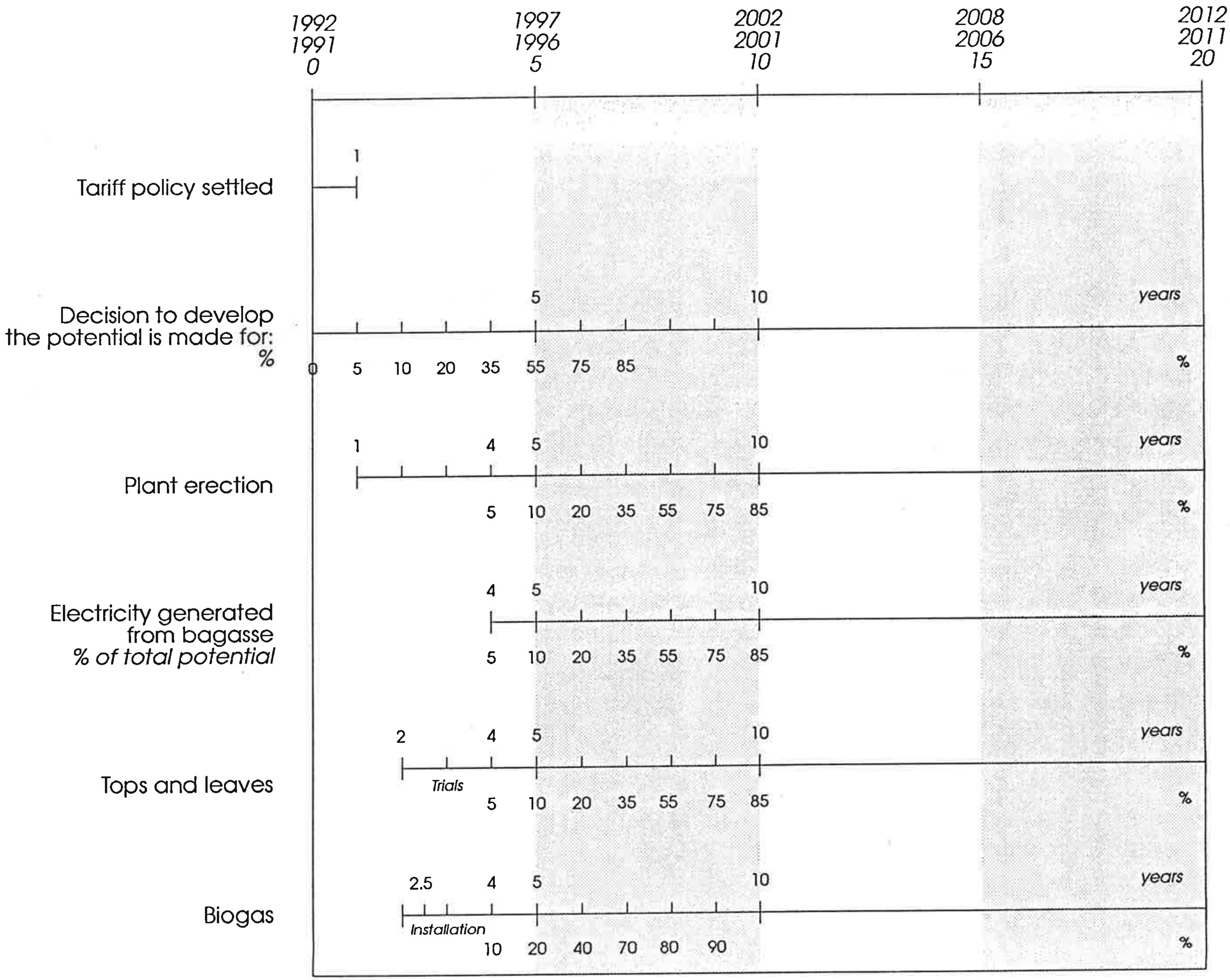


Fig 4.6: Sugar cane residues · CEST conversion system

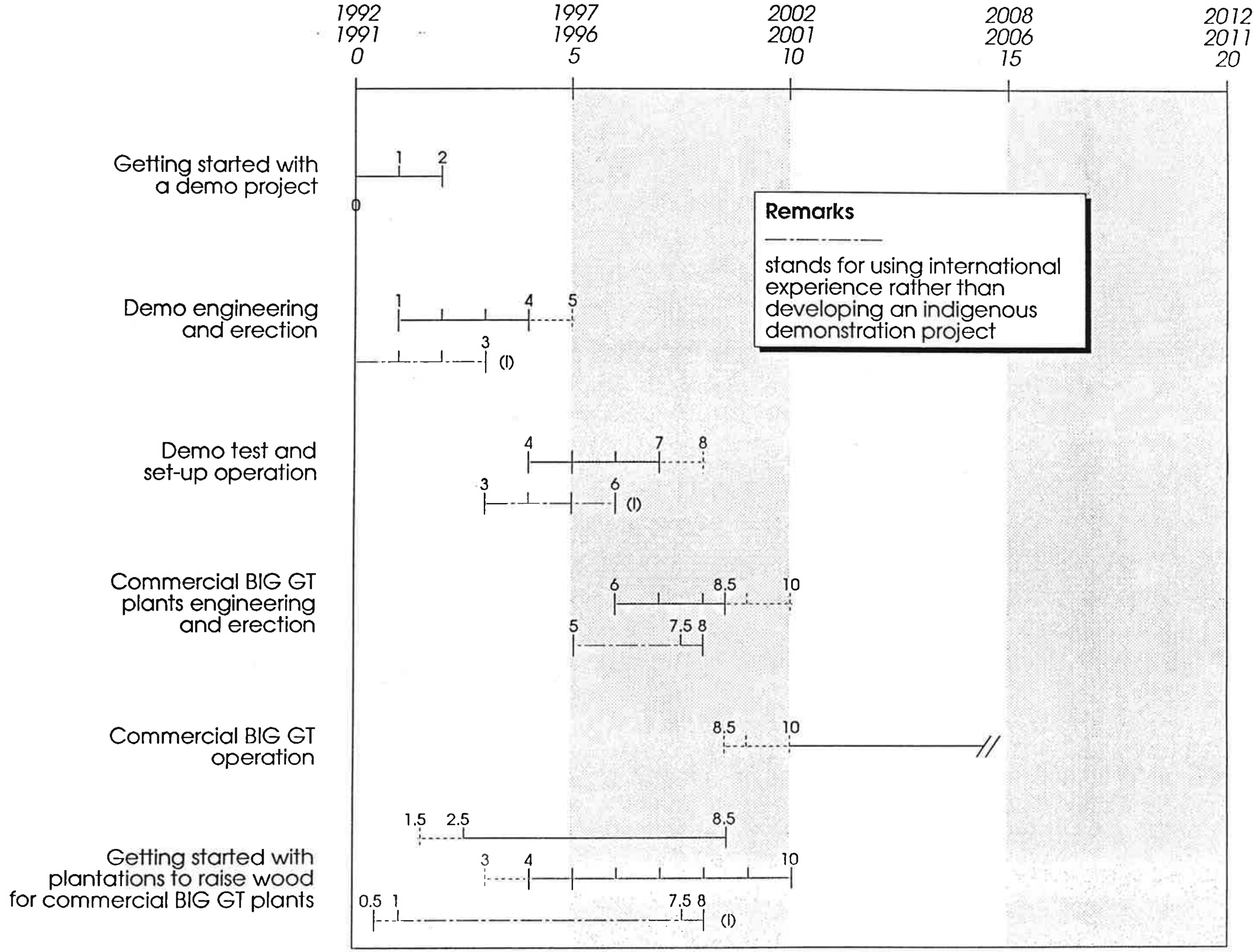


Fig 4.7: Wood or sugar cane residues · BIG GT conversion system

4.7.2 ANALYSIS FROM THE INVESTMENT STANDPOINT

As an accurate investment analysis based on a specific site or program is not possible, the intention here is to show average numbers and compare them with other well known investment yardsticks. The investment estimates are based upon the data developed in previous sections. Table 4-33 contains the total investment that would be needed to make use of the sugar cane residues as a prime energy source for electricity. It amounts to approximately US$5.0 billion or around US$ 0.72 billion a year, if a 7 development year time frame is considered. This is more or less what CHESF, the Northeast regional utility, has been investing in its basically hydroelectric system during the last 4 or 5 years.

It is also seen that, from the investment point of view, there is no difference between the existing CEST technology and the new BIG-GT, so it is another clear indication in the direction of pursuing its development as soon as possible.

Table 4-34 shows the same kind of information for wood. In this case, since a larger electricity potential is involved, a development time frame of 20 years has been considered. Although the investment in wood plantations must be made approximately 3 years in advance of the power plant, they are shown added up in Table 4-34. The investment in fuel production (wood plantations) accounts for 34%, 23% and 21% of the total for the BIG GTOC, BIG STIG, and BIG GTCC systems respectively. The total investment requirements are between US$ 20.5 billion and 32.7 billion in 20 years, with an average annual spending between US$ 1.03 billion and US$ 1.64 billion. Comparing the annual investment with the Northeast GNP for 1988, it represents between 2.5% and 3.9%.

A comparison of the annual investment in both cases (wood or sugar cane residues) with the estimated requirements to complete the demonstration phase of the BIG-GT technology (estimated between US$ 35 and 50 million) indicates that the financial resources required for its development should not be the main focus in deciding whether to invest in the BIG-GT system. Its long term benefits should be the main consideration.

Finally, Table 4-35 contains a first idea of the local (Brazilian) and foreign currency percentages included in the investment for the sugar cane residues and wood plantations programs. It is important to have in mind that the present numbers are preliminary, valid for the beginning of the program, and that local currency participation should increase with time.

TABLE 4-33 SUGAR CANE RESIDUES INVESTMENT REQUIREMENTS FOR ELECTRICITY PRODUCTION ON A UTILITY BASIS

Conversion system	\$/kw	Install. Cap MW	Total Invest. \$ billion	Annual Invest 10^9 US \$
CEST	2100	2334	4.90	0.700
BIG-STIG	1170	4261	4.99	0.713

Remarks: Installed capacity, 85% of the total potential shown in Table 4-19
Assumed that the potential would be developed in a 7 year time frame as shown in Fig. 4-2.

TABLE 4-34 WOOD INVESTMENT REQUIREMENTS FOR ELECTRICITY PRODUCTION

Conversion System	Invest. Spec. Cost Wood Prod. \$/ha	Conv. Syst. \$/kw	Installed Capacity MW	Wood Area 1000 ha	Total Invest 10^9US\$	Annual Invest 10^9US\$
BIG GTOC	898	947	14350	7.720	20.53	1.03
BIG STIG	898	1170	20350	7720	30.73	1.54
BIG GTCC	898	1113	23175	7.720	32.73	1.64

Remarks: Installed capacity, based on the potential shown in Table 4-24 and 0.85 capacity factor.

Wood production investment assumed as the average between the low and high investment cost, for wood plantations initial investment (L 576 \$/ha; H 1220 \$/ha)

Annual investment calculated on a 20 year basis.

TABLE 4-35 FOREIGN X LOCAL CURRENCY ESTIMATES

Sugar cane	% Foreign	% Local
CEST	12	88
BIG STIG	49	51

Wood	% Foreign	% Local
BIG GTOC	24.4	75.6
BIG STIG	37.7	62.3
BIG GTCC	29.2	70.8

Remarks:

CEST — Considered as imported, the boiler, 50% of Turbogenerator and 50% of the piping

BIG GT — Considered as imported, 70% of the gas turbine system, 20% of the gasification, the HRSG, 50% of the steam turbo generator in the case of BIG GTCC

Wood planatations 100% local currency

4.7.3 ANALYSIS FROM THE EMPLOYMENT STANDPOINT

The basis for the employment analysis is the information in Tables 4-15 through 4-18. It will be made separately for sugar cane residues and wood plantations, as the two cases pose different situations.

For the sugar cane agroindustry efficiently using of its residues, including tops and leaves, the most significant effect from the employment standpoint would be a substantive decrease on the lay-off rates during the off-season period, as compared with the present situation. Using the tops and leaves provides opportunity to retain most of the jobs that are now lost during the off-season period by shifting field laborers from harvesting to baling activities. Table 4-36 shows that for a standard Northeast sugar cane season, the efficient use of its residues would retain during the off-season period more than 72,000 jobs. This number increases to almost 99,000 jobs in a high production season. Of course as the production for various seasons varies around the average the first number is more significant. It is also important to remember that these estimates are based on averages for the country and that the Northeast uses more manpower than the Southeast.

To have an idea of the cost of the jobs retained in the off-season period, it was assumed that it only would occur with the installation of BIG STIG or CEST systems to produce electricity. Using their investment costs, a retained job would cost about US $ 50654.00. It is important to have in mind that actions to use the sugar cane residues can be taken using the existing installations, which means at a much lower, or in specific cases, at almost no cost. Finally it is interesting to observe that as the sugar cane production in Northeast Brazil is concentrated in the states of Pernambuco and Alagoas, they are the ones that bear the largest part of the burden related to the social problems caused by the sugar cane industry off-season lay offs.

TABLE 4-36 SUGAR CANE AGROINDUSTRY EMPLOYMENT, ACTUAL SITUATION VERSUS EFFICIENT USE OF ITS RESIDUES IN NORTHEAST BRAZIL

Lost jobs during the off season period -Ne

	M/ha	For the Average Sugar cane product.	For the Highest Sugar cane product.
Present Situation	0.075	88637	121364
W/ efficient use of residues	0.014	16546	22655
Retained jobs by eff. residue use		72091	98709

Remarks: Average sugar cane production per harvest in Northeast Brazil: 52000000 t

Best harvest sugar cane production in Northeast Brazil: 71200000 t

Average sugar cane yield for the Northeast Brazil: 55 t_c/ha.cut, 4 cuts per cycle, 44 t_c/ha.y

Regarding wood plantations the situation is different, as the focus is on new jobs that may be created with a wood for electricity program. Table 4-37 shows that a wood program, with plantations covering no more than 5% of each Northeast state, approximately 240,000 new jobs would be created. Of these, 211,500 would be in growing wood and 28,500 would be in the convertion facilities (power plants), or 7.4 agricultural employment opportunities per industrial job.

The overall cost per employment created would be around US$ 132,400, with an agricultural job costing around US$ 32, 700,00 and an industrial US$ 870,000, or 26.6 time more. Considering its development over a 20-year period, this would represent 12,000 new jobs per year, which is about the number of employees that CHESF

(Companhia Hidroelectrica do Sao Fransisco), the region major utility, had in 1989.

Of those jobs, about 8000 would require highly skilled professionals, 17,663 would require a moderate skill level and 214,369 would be unskilled jobs. As most of the laborers would be employed for wood plantations, the demand for new forestry professionals would probably represent a high burden on the existing educational infrastructure, requiring new investments in this area. As the numbers shown in Table 4-37 are related to direct jobs, it can be foreseen that at least the same amount would be created by indirect activities. This would bring the total number of employment opportunities related to a wood program of the magnitude forseen here to approximately 500,000.

TABLE 4-37 WOOD PLANTATIONS FOR ELECTRICITY PROGRAM EMPLOYMENT OPPORTUNITIES

	Convention (Power Plant)	Agricultural	Total
Jobs	28564	211528	240092
$/job	870046.00	32734.00	132385.00
Job Qualification			
H	1714	6346	8060
M	2856	14807	17663
L	23994	190375	214369

Remarks: Basic information from Table 4-17, 4-24, and 4-34
Assumptions made:

- agricultural phase 0.0274 M/ha
- convertion phase 0.0037 M/ha

Wood program area 7.72 million ha
Wood investment cost; $ 898.00 per ha
Convention system investment cost; $1140 per kw

Capacity factor:	0.85
Energy:	18500 Mwy/y
Installed capacity:	21800 MW

Investment

Wood plantations	6.93 billion $
Convention system	24.85 billion $
Total	31.78 billion $

Manpower qualifications (%)

	Agricult.	Convention
High	3	6
Medium	7	10
Low	90	84

4.8 ANALYSIS FROM THE ENVIRONMENTAL STANDPOINT

As with any human activity, the use of biomass for electricity may cause new stresses on the local environment. In this case its inherent benefits may offset its hazards. As a live natural resource, biomass, differently from other energy sources, has an active interaction with the environment. The major environmental concerns from its extensive and intensive use are related to over-fertilization, soil damage and or erosion, over-use of pesticides or herbicides and modifications to the natural habitat of some animal species.

Lately, increasing concerns with impairing biodiversity by intensive use of biomass resources has been a point of discussion by environmentalist groups. The experience in Brazil with wood plantations has shown that the use of fertilizers, pesticides and herbicides can be properly controlled and that they only become a problem when no attention is given to thier use.

Regarding the soil, plantations, more than a cause of damage, have been used to try to solve most of its problems and improve its conditions. Attention should be paid to the appropriate equipment and the proper techniques for using them during implantation and harvesting.

Modifications in habitat are impossible to avoid, so the study of the best layout to minimize its effects must be carefully made. The proper choice of species and plantation layout may, on certain occassions even enhance environmental and habitat conditions.

On the other hand the use of plantations provides energy with a neutral CO_2 balance. They may also improve water storage conditions in the soil. They may provide soil protection and impede increasing soil and local ambient temperatures. All together it seems that the careful use of biomass may be one of the most environmentally friendly ways of producing electricity.

4.9 CONCLUSIONS

The main conclusions that can be drawn from the analysis made about the possibilities of using biomass for electric energy production in Northeast Brazil are as follows:

(a) The best technology to get the most efficient use of the existing and potential biomass resources in the region is the gasification gas turbine technology. Although a demonstration phase must be completed its high efficiency and low will cost more than offset the present difficulties.

(b) Total electricity costs of US$ 36.00 per MWh can be achieved with the gas turbines, making the biomass option a highly competitive alternative to produce electricity.

(c) The potential to be explored is significant. Wood plantations would be able to produce as much as 19% of the country's hydro resources using no more than 5% of the Northeast's land.

(d) The efficient use of biomass in the sugar cane industry may in decrease off-season layoffs, contributing to the solution of one of the industry's major problems. A wood for electricity program based on plantations may provide a large number of new employment opportunities, mainly in agricultural areas.

(e) Biomass may be considered one of the most environmentally friendly alternatives for producing electricity.

(f) The initial investment necessary to complete the demonstration phase and bring the biomass gasification gas turbine technology to a commerical stage may be considered minimal if compared with the financial resources normally used in the electric energy industry.

(g) An efficient use of biomass for electricity program will take around 7 to 8 years to produce its first results.

(h) A preliminary estimate of the income distribution in a biomass for energy program indicates that between 38% and

48% of revenues would go to worker salaries.

5. POSSIBLE RESULTS FROM A BIOMASS FOR ENERGY POLICY - A SCENARIO FOR THE NORTHEAST.

A very important step forward in the decision process to improve and extend the range of biomass use in Brazil would be, even on a preliminary basis, to try to qualify and quantify the foreseeable results of a sound pro-biomass energy policy. Clearly it will not be a precise exercise, as the basic information carries an inherent level of uncertainty, and some aspects of the issue deserve more research and study to achieve a higher degree of accuracy. It is also important to understand that the available information has different levels of quality. As an example, CHESF (Campanhia Hydro electrica do Sao Francisco) the regional power utility for the Northeast, has studied to a long extent the prevailing conditions in its area of operation. This has been going on for some years now, and a broad set of data have been collected and analyzed. The same may not be said of all regions of the country, where data have been gathered on a more scattered basis and with different aims. A really accurate evaluation probably would require a specific "Process analysis study" or an "Input - Output" evaluation, which are beyond the scope of this study.

This chapter we will be looking at the Northeast situation and its possibilities. Subsequently, further studies may focus on the country as a whole.

The idea is to start from the present situation and actual plans for energy supply and then analyze the results of possible extended use of biomass for energy under a new policy scenario.

The main information basis will be the data developed in chapters 3 and 4.

5.1 ASPECTS OF A BIOMASS FOR ENERGY POLICY IMPLEMENTATION IN NORTHEAST BRAZIL.

To restrict the area of analysis, the focus will be on electricity production and on sugar cane and wood plantations, which are, for practical purposes, the two main biomass sources with real development possibilities.

The intent is, using actual data, to compare hydro and biomass alternatives from the energy, investment and employment standpoints.

Table 5.1 contains basic data about wood and sugar cane relating to electric energy production, which permits a good comparison between the two resources. It is clear that in the long run, wood can offer a higher potential, more job opportunities and a lower average electricity cost. In the short term, however, the existing sugar cane infrastructure must be taken into consideration. It is also clear that at present both resources cannot be counted on as a reliable energy source.

TABLE 5.1 WOOD PLANTATIONS AND SUGAR CANE ENERGY DATA COMPARISON FOR THE NORTHEAST BRAZIL.

	Wood Plant	Sugar Cane
Present Planted area (ha)	0	1,400,00
Achievable planted area (ha)	7,720,000	1,620,000
Energy potential (MWy/y)		
At present	0	24
Achievable	18,500	3,296
Installed Capacity (MW)	21,800	5,013
Investment 10^9 \$	31.78	5.87
New job opportunities for the total energy potential develop.	240,100	98,700
Average Energy Cost \$/MWh	38.8	39.6 - 43.5
Minimum Energy Cost \$/MWh	31.7 - 34.5	28.4

Remarks:
- Information basis chapter 4.
- Present planted area for sugar cane: mean, between the area for the highest harvest, 71200000t and the average Northeast harvest, 52000000t. Sugar cane yield, 55 t/ha.cut or 44 t/ha.y.

- Maximum planted area is the area correspondent to the highest harvested production.

- Sugar cane yield (Ref. 1) Tecal.

- Investment, jobs and energy cost, refers to the maximum potential.

- Minimum energy cost, refers to 40 m^3_{sol}/ha.y sites, for wood and use of bagasse only as fuel, in this case the potential would be of 1707 MWy/y.

- Investments are related to energy conversion facilities only, no process modifications are included.

- Average cost for bagasse considers the use of tops and leaves and a bagasse cost between 1.5 $/$t_{sc}$ and 3$/$t_{sc}$. To calculate the present energy potential, it was used the data of ref. (2), bagasse with 50% moisture, 21 kgt/cm^2; 300°C steam, 2.5 kgF/cm^2 back pressure steam turbines, which results in a 4.0 kwh/t_{sc} electric energy surplus.

- 52000000 t_{sc} harvested per year.

Table 5.2 shows basic data about the hydro resources existing in Brazil's Northeast, which are exploited by CHESF. It also contains data about the electric generation capacity, production and costs. The data in the table reflect, in a very concise way, the basic characteristics of the region's hydroelectric system and what has been planned for its future development. About the information itself, it is important to be clear, even considering that the level of precision decays, for the power plants for which construction is foreseen in the far future, its invaluable value, as an overall insight on the regional hydroelectric system and its future possibilities.

Its overall installed capacity amounts to 14092 MW, its electricity production to 7409 MWy/y, with investments in the range 20 billion US dollars, referred to 1990.

Based on the aforementioned information, Figures 5.1 and 5.2 show the evolution of the investment and electricity production costs for the last 50 years and in both cases, the upward trend is very clear.

Table 5.3 contains the total investment planned for the CHESF hydro system and the amounts to be invested in after 1990, from 1990 to 2000 and from 1994 to 2000. It's interesting to note that 66% of the investment has yet to be made. Of this, 45% is planned between 1990 and the year 2000, but only 14% between 1994 and 2000 when the Xingo I power plant is supposed to be completed.

TABLE 5.2 CHESF HYDRO ELECTRIC SYSTEM CHARACTERIZATION (3)

Commission	Name	Units	MW	MWy/y	$10^6 invest. cost wo/idc	w/idc	$/kw wo/idc	w/idc	$/MWh	MWy/y / km²
54/61/71	PA I, II, III	13	1524	895	230	230	151	151	4.5	179.00
70	B. Esparanca 1	2	100	94	157	157	1453	1453	20.2	0.26
77	Moxoto	4	440	234	548	548	1246	1246	28.6	2.52
79	Sobradinho	6	1045	1067	1507	1507	1442	1442	17.1	0.25
79	PA IV	6	2460	287	793	793	323	323	39.4	19.13
94	Xingo I	6	3210	2094	3056	4064	952	1266	23.7	24.64
90	B. Esperanca 2	2	126	32	106	106	840	840	41.5	0.09
87	Itaparica 1	6	1500	890	2461	3116	1641	2077	41.8	1.07
-	Pedra Branca	7	1088	600	2227	2824	2047	2595	55.8	0.49
-	Belem	6	672	326	1239	1571	1844	2338	57.3	0.97
99	Araca	2	120	74	240	283	2000	2360	45.5	0.62
2000	Itapebi	3	375	208	860	860	2293	2293	49.2	3.20
-	Paratinga	8	440	184	863	1011	1962	2298	65.4	0.08
98	Sacos	4	114	64	248	292	2173	2565	54.2	4.57
-	Salto da Divisa	3	174	95	717	717	4120	4120	88.5	0.13
96	Pedra do Cavalo	2	300	95	352	454	1174	1514	57.8	0.58
-	Gatos 1	2	30	15	73	87	2448	2890	68.3	0.15
-	Gatos 3	2	36	28	115	136	3207	3785	57.2	0.28
-	Pao de Acucar	6	330	127	1124	1316	3406	3988	121.6	3.97
	Total		14092	7409		20072				

Source: CHESF DOCG

Remarks: Costs Referred to April 90.
US$ 1.00 = CR$ 48.69
O&M Cost - 7.69 $/kw.y = 0.83 $/mwh 0,88
Transmission costs not accounted
* Refers to the reservoir maximum area

CHESF EVOLUTION OF INVESTMENT COSTS

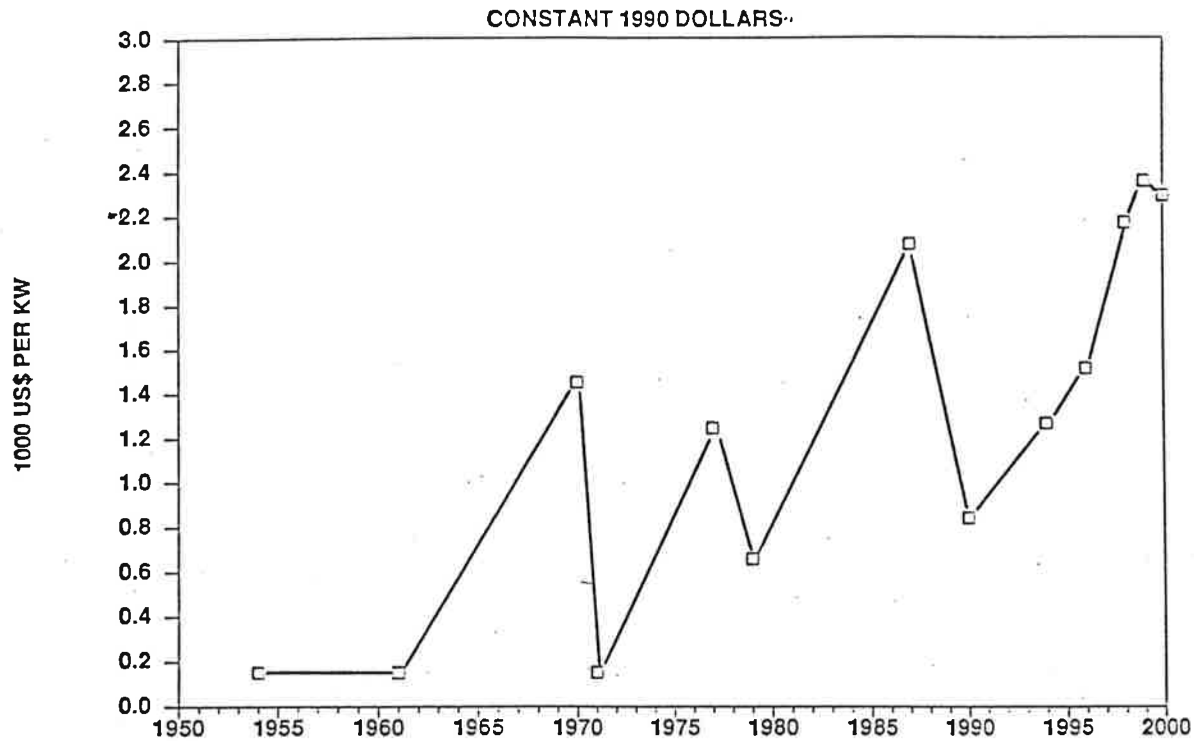


Fig. 5.1

CHESF EVOLUTION OF PRODUCTION COSTS

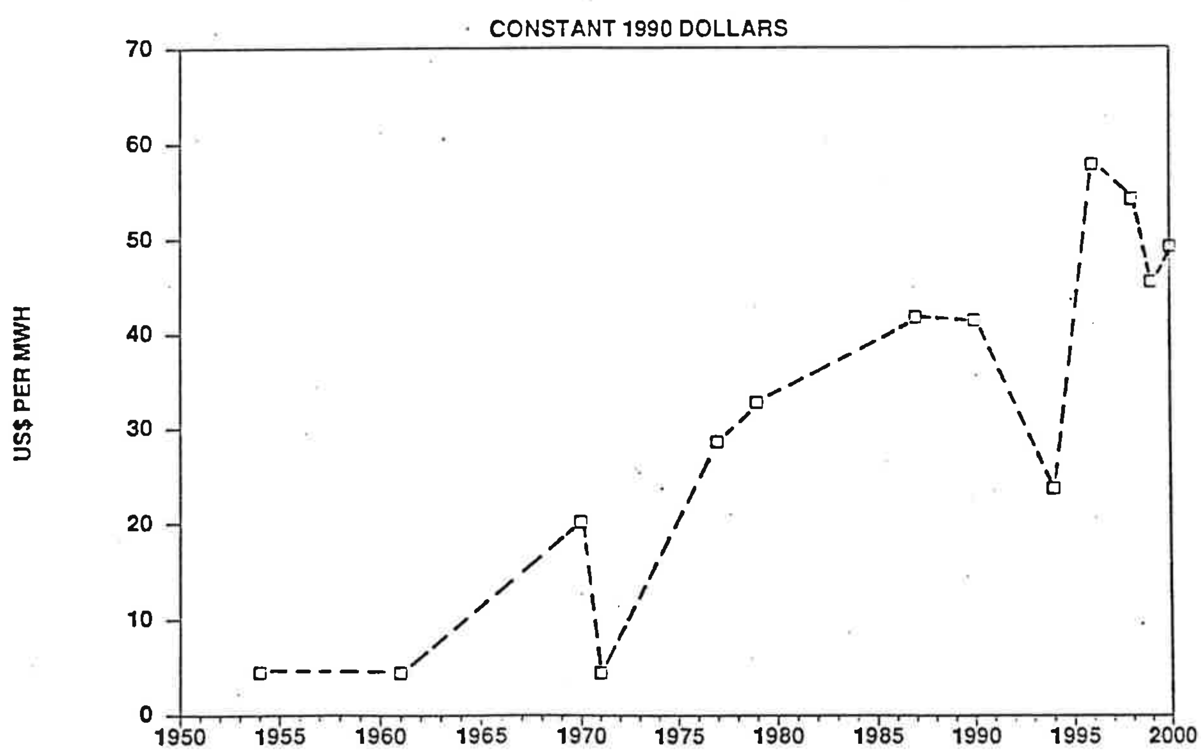


Fig. 5.2

TABLE 5.3 CHESF HYDRO SYSTEM INVESTMENT COST (1990)

10^6 US$

Power Plant	Commission Year	Total	1990 and after	1990 to 2000	1994 to 2000
PA I,II,III	54,61,71	230			
Boa Esperanca I	70	157			
Moxoto	77	548			
Sobradinho	79	1507			
PA IV	79	793			
Xingo I	94	4064	4064	4064	
Boa Esperanca II	90	106			
Itapanica I	87	3116			
Pedra Branca	-	2824	2824		
Belem	-	1571	1571		
Araca	99	283	283	283	283
Itapebi	2000	860	860	860	860
Paratinga	-	1011	1011		
Sacos	98	292	292	292	292
Salto da Divisa	-	717	717		
Pedra do Cavalo	96	454	454	454	454
Gatos I	-	87	87		
Gatos III	-	136	136		
Pao de Acucar	-	1316	1316		
TOTAL		20072	13165	5943	1889

Table 5.4 shows, for the same periods, the electricity production added to the system as well as the total production that will be possible when all the systems hydro power plants have been completed.

In this case, about 53% is supposed to be realized after 1990 and of this, 65% in the period 1990 - 2000, but only 11% between 1994 and 2000. In other words, the Xingo I power plant will be practically the only investment in the hydro system during the 1990 decade.

Table 5.5 compares the basic parameters for the hydro and biomass resources and some interesting conclusions may be drawn.

First, the total biomass installed capacity and investment are double that for the hydro, but the total biomass overall electricity production potential is about triple that of hydro.

Second, although the investment cost for both resources are in the same range, the average cost is around 43% higher for the hydro system, and the 24% lower total production cost for the hydro system basically reflects the longer life time of its facilities (50 years versus 25 years).

TABLE 5.4 CHESF HYDRO SYSTEM ENERGY

MWy/y

Power Plant	Total	1990 and after	1990 to 2000	1994 to 2000
PA I,II,III	895			
Boa Esperanca I	94			
Moxoto	234			
Sobradinho	1067			
PA IV	287			
Xingo I	2094	2094	2094	
Boa Esperanca II	32			
Itapanica I	890			
Pedro Branca	600	600		
Belem	326	326		
Araca	74	74	74	74
Itapebi	208	208	208	208
Paratinga	184	184		
Sacos	64	64	64	64
Salto da Divisa	95	95		
Pedra do Cavalo	95	95	95	95
Gatos I	15	15		
Gatos III	28	28		
Pas de Acucar	127	127		
TOTAL	7409	3910	2535	441

TABLE 5.5 BASIC PARAMETERS FOR CHESF HYDRO SYSTEM AS COMPARED WITH WOOD PLANTATIONS AND SUGAR CANE RESIDUES (1988)

		CHESF Hydro System	Wood Plantations	Sugar Cane Residues
Total Investment	10^9\$	18.61	31.78	5.87
Total Installed Capacity	MW	14092	21800	5013
Total Energy Capacity	MWy/y	7409	18500	3296
Facilities Life	y	50	25	25
Average Installed Cost	\$/kW	1218.93	1457.80	1171.00
Average Energy Cost	1000\$ / MWy/y	2508.50	1718.00	1781.00
Average Energy production cost	\$/MWh	30.50	38.8	41.60

Remarks: US Currency adjustment factor: US GNP implicitly deflector.
1988: 121.3 1990: 131.0

Basic information as of chapter 4, Table 5.1, and Table 5.2

Installed cost for wood plantations accounts for agricultural and conversion facilities. Installed cost for sugar cane accounts only for conversion facilities, all process cost necessary to permit to use BIG-STIG systems, on sugar cane mills and or distilleries, are supposed to be made independently and paid by the sugar and or alcohol production. CHESF -stands for Companhia Hydroelectrica do Sao Francisco - the Northeast Brazil power utility.

Table 5.6 shows the evolution of CHESF hydro system parameters after 1990. Although the numbers are impressive by themselves, it is important to stress the main message it contains. The first interesting aspect is that for the 1990 decade the average electricity production cost will be 13.4% lower than the total average system production cost. Within 10 years, however, the 1994 - 2000 period shows a cost 55.4% higher than the average system production cost. After 2000, the production cost will be almost 116% higher than the average. All this reflects the exhausting of the region's hydro resources.

TABLE 5.6 CHESF HYDRO SYSTEM BASIC PARAMETERS EVOLUTION (1988 - US$)

		Total System	After 1990	1900-2000	1994-2000	After 2000
Investment	$10^9$$	18.61	12.6	5.51	1.75	7.10
Installed Capacity	MW	14092	6889	4119	2025	2770
Energy Capacity	MWy/y	7409	3910	2535	441	1375
Installed Capacity Cost	1000$/MW	1319	1829	1338	864	2535
Energy Capacity Cost	1000$ / MWy/y	2509	3223	2174	3968	5164
Energy Production Cost	$/MWh	30.5	38.6	26.4	47.4	65.8

Tables 5.7 and 5.8 show for the same amount of investment intended to be made by CHESF in its hydro system what could be achieved, if instead the investments were made in biomass.

Again the numbers are impressive. For both resources the electricity production costs are sensibly lower than the ones achieved by the hydro and the "installed capacity" and "energy capacity" are much larger.

Table 5.9 shows a comparison between the hydro and biomass proposals, in terms of investment and employment opportunities, for the same amount of electricity production foreseen in the present generation plans using CHESF hydro resources.

The results show that the same amount of electricity could be produced with 36% of the forecasted hydro investment, if biomass were used. From the employment standpoint, the utilization of wood would provide 5 times more job opportunities. If sugar cane residues, including tops and leaves, are used the jobs retained during the off-season period would be 12 times higher than the hydro option would provide. It is important to emphasize that the realization of jobs retained by the use of sugar cane residues during the off-season period will be possible only if the tops and leaves are used as an off-season fuel.

If just the bagasse were used, not only would no jobs be retained, but the overall electricity production potential would decrease to approximately 1707 MWy/y.

TABLE 5.7 BIOMASS ENERGY PRODUCTION USING THE SAME INVESTMENT INTENDED TO BE USED IN CHESF HYDRO SYSTEM (1988 US$)

		After 1994		After 2000	
Investment Forecast	$10^9$$	8.85 wood	5.87* sugar cane	7.10 wood	5.87* sugar cane
Installed Capacity	MW	6070	5013	4870	5013
Energy Capacity	MWy/y	5151	3296	4133	3296
Installed Capacity Cost	1000$/MW	1458	1171	1458	1171
Energy Capacity Cost	1000$ / MWy/y	1718	1781	1718	1781
Energy Production cost	$/MWh	38.8	41.6	38.8	41.6

Remarks: *Limited by the maximum sugar cane energy potential.

TABLE 5.8 BIOMASS ELECTRICITY VERSUS HYDROELECTRICITY IN NORTHEAST BRAZIL

	After 1994		After 2000	
Investment Forecast 10^9\$	8.85		7.10	
	MW	MWy/y	MW	MWy/y
CHESF Hydro System	4795	1816	2770	1375
Wood	6070	5151	4870	4133
Sugar cane	5013	3296	5013	3296
Wood + sugar cane	6800	5062	5456	4061

Remarks: For the wood + sugar cane the installed power is the one that maximizes the energy output for a certain amount of investment. See Appendix A5-1 for details.

TABLE 5.9 INVESTMENT NECESSARY TO PRODUCT THE SAME ENERGY FORESEEN FOR THE CHESF HYDRO SYSTEM AND EMPLOYMENT DATA (1988 US$)

	After 1994		After 2000
Energy to be produced - MWy/y	1816		1375
		$10^9$$	
CHESF hydro system	8.85		7.10
Wood	3.12		2.36
Sugar cane	3.23		2.45
Employment (M)			
Wood new job opportunities	22990		17407
Sugar cane job retained by the use of T&L	54456		41231
Hydro new job opportunties	4584		3470

Finally, Tables 5.10 to 5.12 show the basic parameters for the most likely hydro power plants to come into operation after 2001 in Brazil's North region's hydroelectric system. The data in these three tables indicate the possibility of realizing an installed capacity close to what can be achieved with wood plantations occupying no more than 5% of the Northeast states. In terms of electricity production, however, it reaches only 43% of what could be produced with wood.

Their power investment costs are comparable, but their electricity costs are much higher than for wood.

As the hydro installations have a much longer life (50 versus 25 years) than the thermal units, their final energy production cost is slightly lower than the average wood energy production cost.

Table 5.12 shows in terms of investment and energy costs the effect of the incorporation of these new power plants in the Ne/N electric system. The main result is a reduction in the average electricity production cost from \$65.8 per MWh to \$41.8 per MWh, which is slightly higher than the same figure for wood (\$38.8 per MWh).

All this indicates that even if the North and Northeast hydro resources are considered together, biomass still has a role to play. More importantly these resources can and should be used as complementary energy sources.

TABLE 5.10 BASIC PARAMETERS OF THE MOST PROBABLE HYDRO POWER PLANTS TO COME INTO OPERATION IN THE NORTH/NORTHEAST ELECTRIC SYSTEM AFTER THE YEAR 2001 (1990 US$)

Power Plant Name	River	Present Situation	# of Units	Energy Capac. MW	Energy Capac. MWy/y	Invest. $10^6$$	$/kw	$/MWh
Serra Quebrada	Tocantins	Feasibility	9	1450	875	2584.50	1782.42	35.5
Estreito	Tocantins	Inventory	8	1200	744	2521.53	2101.28	40.4
Tupirantins	Tocantins	Inventory	7	1000	590	2420.45	2420.45	48.7
Lageado	Tocantins	Inventory	6	800	413	1751.17	2188.97	50.5
Ipueiras	Tocantins	Inventory	4	600	332	1691.40	2819.00	60.2
Belo Monte	Xingu	Feasibility	20	11000	3800	10774.83	979.53	35.2
Santa Isable	Araguaia	Feasibility	10	2200	1235	5119.08	2326.85	49.3
				18250	7989	26862.96		

Remarks: Source CHESF - DOCG (3)
Numbers refer to March 1990 US$ 1.00 = CR$37.82
O&M cost 9.90 $/MW.y or 1.1 $/MWh

TABLE 5.11 COST AND ENERGY PARAMTERS OF THE HYDROPOWER PLANTS TO BE BROUGHT IN OPERATION AFTER THE YEAR 2001 IN THE NORTH BRAZIL

		(1990)	(1988)
Investment	10^9\$	26.863	24.874
Installed Capacity	MW	18250	18250
Energy Capacity	MWy/y	7989	7989
Installed Capacity Cost	1000\$/MW	1472	1363
Energy Capacity Cost	1000\$ / MWy/y	3362	3113
Energy Production Cost (average)	\$/MWh	40.7	37.7

Remarks: Correction factor
US GNP implicit deflector 1988 - 121.3
1990 - 131.0

Ref. (3)

TABLE 5.12 NORTHEAST AND NORTH HYDRO SYSTEMS COST AND ENERGY PARAMETERS (1988 US$) (3)

		1990-2000 Northeast	After 2000 Northeast	After 2000 North	After 2000 Northeast + North
Investment	$10^9$$	5.51	7.10	24.87	31.97
Installed Capacity	MW	4119	2770	18250	21010
Energy Capacity	MWy/y	2535	1375	7889	9364
Installed Capacity Cost	1000$/MW	1338	2563	1363	1521
Energy Capacity Cost	1000$ / MWy/y	2174	5164	3113	3414
Energy Production	$/MWh	26.4	65.8	37.7	41.8

5.2 A SUGGESTION TO DEVELOP BIOMASS IN NORTHEAST BRAZIL

All the information developed up to this point strongly indicates that the use of biomass in an efficient way can be one of the best alternatives for producing electricity in the Northeast. Changing the potential situation into reality will only be possible through a demonstration phase which is needed to prove the commercial viability of the technology.

Thus, it is of fundamental importance to develop a professional and sound demonstration program. The demonstration program must involve not only the conversion technology, but also the fuel production phase. The fuel production should be understood as comprising the development of wood plantations and the use of sugar cane residues for energy.

Table 5.13 shows the main topics that should be addressed in a biomass for energy development program.

Finally, a program like this should be very well coordinated, with responsibilities, authority, resources (human and financial) and goals clearly specified.

Tables 5.14, 5.15 and 5.16 show some of the most important parameters concerning the three agro-energy industries studied in the past chapters. It is interesting to note that they are remarkably different in most repects.

Palm oil requires lots of water and fertilizer and has a longer life cycle, with one cut at the end. It is done not for harvesting purposes, but for practical and economic reasons.

Wood plantations require the lowest amounts of manpower, almost three times less than sugar cane and almost seven times less than palm oil. The costs per tonne of product are in the same range for wood and sugar cane. Palm oil is three to six times more costly. These numbers illustrate how different the three industries are. They reflect profound differences in technology, skills, and knowledge required by each.

TABLE 5.13 BIOMASS FOR ENERGY PROGRAM - MAIN AREAS OF CONCERN

Wood Production

Human Resources:	Is of fundamental importance to prepare the personnel, necessary to technically support the program. These people will be the ones that will assure that high yields and the wood required quality will be achieved.
Data Base:	It is very important to form a sound and reliable base of data to support the program and make possible to prioritize the best sites, for wood plantations development.
Forest Management:	It is very important to have the best information and technology, for the various environments where forests will have to be managed, inside the Northeast region. The environmental aspect should be a constant presence on wood plantations developments.
Model for forest development:	It is very important to develop a model, for forest implantation, that although implemented under very professional directions will be flexible enough, to take in consideration the local conditions and specific needs.
Demonstration Project:	It is very important to have a practical demonstration of a forest, grown on a short rotation basis, being managed to operate coupled with a thermal power plant.

Sugar Cane Residues

Human Resources: It is important to improve the average quality of the personnel that actually is working in the sugar cane agri industry.

Tops & Leaves Technology: It is of fundamental importance to develop and establish a technology to use the sugar cane tops and leaves. It is the possibility of its utilization that will provide, not only a high amount of energy, but the retainment of a large number of jobs during the off season period.

Demonstration Project: It is of fundamental importance to have the sugar cane residues, used as a fuel for the gasification-gas turbine technology, to discover and solve all the problems inherent to its use.

Conversion Technology

Human Resources: As in the other cases, the support of skilled professionals is of fundamental importance to the program success.

Demonstration Project: To reach the commercial phase of the biomass gasification gas turbine technology it is vital to have a demonstration project, whose size, may be considered a module for the commercial units and where all its operational problems can be discovered and solved.

TABLE 5.14 PHYSICAL PARAMETER COMPARISON

		Sugar Cane	Wood Plantations	Palm Oil Plantations
Climate				
Temp.	°C	26 - 33	15 - 28	22 - 33
Rainfall	mm/y	1200 - 1500	700 - 1500	>2000
Soil		Low Constraints	Low Constraints	Some Constraints
Fertilizers	kg/ha	3730	860	3139 - 23539
Herb. + Pest.	kg/ha	15.2	18.2	110.5
Fuel	kg/ha	957	1670	189
Life Cycle (y)		5	18	25 - 30
Cuts per Cycle		4	3	1
Yields:	t/ha	260	383.4	483
	t/ha.y	52	21.3	23
	t/ha.cut	65	127.8	483

Remarks: Sugar cane - present situation
Wood plant - yield 30 m^3_{sol}/ha.y 33% moist.
Palm oil - fuel - transport only

TABLE 5.15 JOB REQUIREMENTS COMPARISON

	M/ha		
	Sugar Cane	Wood Plantations	Palm oil
Plantations			
Agricultural	0.086	0.0216	0.2486
Transport	0.010	0.0058	0.0076
Processing	0.027	0.024 (1) 0.0044 (2)	0.0252 (3)
Total	0.123	0.0514 (1) 0.0318 (2)	0.2814

Remarks: Sugar Cane - considers the present situation
Wood plantations (1) charcoal production
(2) average for electricity production
Palm oil plant. (3) considers only the bunches processing

Table 5.16 INVESTMENT AND COST COMPARISON

		Sugar Cane	Wood Plantations	Palm Plantations
Investment	\$/ha	967	567 - 1270	3909
Cost	\$/t	15	14.5 - 19	49 - 101

Remarks: Sugar Cane - considers the present situation
Wood plant. - considers a yield of 30 m^3_{sol}/ha.y and 33% moist.
Palm oil - considers the cost per t of bunches.

5.3 CONCLUSIONS

The information developed in this chapter, based on the best available data, permit the following conclusions:

- The actual knowledge of Northeast Brazil's biomass resources coupled with modern electric generation technology has the potential to be one of the most efficient and competitive alternative strategies for producing electricity to meet demand growth in the region.

- As compared with the future utilization of the present, primary regional resource being exploited for electricity production -- hydro -- the biomass advantages may be summarized as:
  - lower investment
  - higher electricity production
  - lower electricity production costs
  - higher employment rates

- The biomass resource can be used in compliment with hydro, enhancing its future range of utilization.

- Given the inherent benefits of biomass and its potential competitiveness from an entrepreneurial standpoint, the investment in a demonstration phase, which is vital to commercialization of the technology, is fully justifiable.

- Not doing so would represent a loss of one of the few opportunities for developing a modern technology to exploit a resource, biomass, that Brazil, unlike many countries of the world, could excell at producing.

6. OVERALL CONCLUSIONS AND A SUGGESTION FOR PRACTICAL IMPLEMENTATION OF A POLICY FOR BIOMASS DEVELOPMENT

This final chapter is aimed at showing in a concise way the main conclusions resulting from this overall study. A second goal is to bring into focus actions that would help encourage the practical implementation of a biomass for energy policy.

6.1 MAIN CONCLUSIONS

As shown, Brazil is a large country with immense natural resources and a large population, but whose policies and management have not been able to translate this huge productive potential into a high living standard for the great majority of its inhabitants. One of the country's peculiarities is its very uneven economic development and population distribution. This situation can be easily seen by comparing the country's area, population and GNP distribution. The Southeast appears with 7% of area, 43.6% of the population and 61.3% of GNP, whereas the Northeast has 18% of the area, 28.5% of the population and contributes only 13.2% of the GNP. The uneveness of the country's wealth also may be seen through other indicators such as unemployment rates, illiteracy and income distribution. Again, the Northeast region appears as the lowest performer. Although the long term tendency is directed toward a more homogenous wealth distribution, the present situation seems to be the paramount problem that must be overcome to reach a point where stronger and more reliable institutions will be able to get the necessary credibility to push the country into a stable pattern of social and economic development. Brazil has a long history of biomass use, as in the case of sugar cane, where more than 400 years of experience have accumulated. Fuel wood was the natural choice to get the energy necessary to cover a broad and varied range of social, commerical and industrial needs. It still maintains a strong presence, as it is the main energy source in some parts of the country.

Charcoal has been in use in Brazil since the 16th century. It was introduced in Minas Gerais more than 175 years ago but only by the end of the 19th century did its importance increase significantly with the extensive development of the steel industry based on charcoal. More recently, about 40 years ago, wood plantations began to replace natural wood for charcoal, and a new impetus for plantations was introduced by the growth of the pulp and paper industry in the country. Nowadays the clear tendency is the replacement of all industrial use of natural wood by wood from plantations. Huge successes in biomass use were achieved in Brazil's recent history. Among them are the sugar cane for ethanol production, wood for charcoal, and pulp and paper production. New possibilities of use are being studied, mainly aiming at electricity production. The environmental aspects are beginning to be understood. More control and a consciousness of the need to preserve as much as possible a healthy environment and prevent unnecessary abuses is starting to pick up. At present, energy from biomass accounts for approximately 28% of the country's energy consumption.

Regarding its geophysical characteristics, most of the country's soils are considered poor for agricultural purposes, but the same cannot be said if the aim is silviculture. The country may be classified as having mild temperatures, high insolation rates and rainfall varying from 500 mm to 3500 mm.

With respect to the basic information about the biomass productive cycle, it could be said that a sound and reliable data base exists and could be used to support future improvements and/or investments in biomass for energy projects.

Regarding the utilization of biomass, or biomass products, for diesel substitution, the indications are that probably the best way to do it would be through the production of palm oil, selling it in the international market and buying direct diesel with the profits made. This would represent an indirect substitution. Although this alternative may look attractive, the size of operations and complexity and implications of a diesel substitution program are such that it is of paramount importance to consider all aspects involved before a decision is made to launch it.

Regarding the conversion systems that could be used to convert biomass into electricity, the advantages of the BIG-GT technology are evident, and a demonstration phase should be pursued and initiated as soon as possible, preferably immediately. In the sugar cane industry the use of tops and leaves should be implemented, and their use should start as an off-season fuel, which will permit a significant decrease, or even the solution, of off-season layoffs. Biomass electricity costs have been shown to be competitive with any other electric resource and the amount of electricity that could be produced in the Northeast may reach more than 20% of what is forecasted to be produced by the entire country's hydro resources. These estimates do not include the large amounts of most agrocrop residues that at present are being wasted.

Biomass production may be considered a manpower intensive activity, providing large numbers of new job opportunities.

An accelerated evolution towards more efficient energy use in the sugar cane industry should be pursued.

For wood plantation implementation careful planning of all its development stages is a must.

Long term energy policies are vital to achieve the full possibilities of a biomass for energy program.

The exhaustion of the Northeast hyrdro resources is a huge opportunity for the exploitation of new energy sources, and biomass appears as one of the main options. Its use not only requires less investment, but also provides a large number of new job opportunities.

The hydro and biomass resources can and should be used complimentarily.

A demonstration program to prove the viability of biomass as a prime energy source for electricity production is of vital importance and should be started as soon possible. To insist on the use of the hydro resource as the sole prime energy source for power production may mean overinvestin in a resource that in the Northeast is close to exhaustion. In fact, as it will take approximately 7 years for a demonstration program to accomplish its goals, it should be initiated immediately.

Finally, to have chances of being successful, a biomass for energy development must be carefully planned and address all the aspects involved, from human resources to its operational details.

6.2 PRACTICAL ASPECTS TO DEVELOP A BIOMASS FOR ENERGY STRATEGY - A SUGGESTION FOR A NEW ENERGY POLICY IMPLEMENTATION

There are indicators that we may be facing the beginning of a new era, a time when new patterns of behavior will have to be achieved to cope with the challenges that will be in front of us. The total picture is not clear, but some aspects are strong enough to be assumed as part of the issues that will have to be addressed by the world community. Two of those aspects are the environmental and social concerns involved in human activities. It seems clear that, on a day by day basis, a stronger and more direct participation of the society in the discussion and solution of its problems will be a matter of fact. This will occur, or already is occurring, at different intensities in various parts of the world. It seems to be a general tendency because, if nothing else, the most progressing examples will tend to be followed. Energy, for sure, will be one of the matters at the center of the discussion. Under this scenario, the electricity production certainly will be one of the main subjects to be addressed. There is no reason to expect it will happen differently in Brazil and, perhaps, this is a discussion that is already going on in the country. There are many signs that the present model adopted by the nation to cope with the supply of electricity is reaching exhaustion. The system is financially stressed, the political interference it permits has been disastrous, and in the last years, the loss of its entreprenurial perspective has badly impaired its capacity to take new challenges. As a consequence, a lack of motivation can be detected throughout the system. On the other hand, the huge investments already in place, the signficant accomplishments already reached and the enormous human resources developed through the years, are assets that must be preserved. These are losses that the country cannot afford, so what seems clear is that all these resources must be redirected to work together and produce the expected and required results.

To achieve this new situtation, it appears to be of fundamental importance to have a deep understanding of what are the real aims and necessities to be addressed. It will require closer work with the community and its organized entities and representatives.

A clear distinction between politics and entrepreneurial activities must be reached.

A sound energy policy, based on real costs and tariffs, must be the realm upon which the new system will have to be built. It also should look for the price that will result in the best economic use of the available resources.

The human resources must be understood to be the major asset of any system, and a policy for excellence will have to prevail.

The research and development activities must be addressed as a fundamental part to overcome the new, and each day more complex challenges that will be faced.

The incorporation in the total cost of the environmental costs, inherent to any energy exploitation, must be pursued.

The system profitably must be used as the main yardstick to measure its efficiency and achievements.

In practical terms all this could be translated into the following steps

- Establishment of tariffs accounting for; the systems real costs, the best economic use of the available resources, the implementation of research and development activities, and the most accurate environmental costs.
- Entrepreneurial management, implying a clear distinction between political and commerical activity.
- Use of profitability as a means to measure the system efficiency. Profitability understood as a social benefit, and not as an aim by itself.

6.3 HINTS FOR A NEW UTILITY COMPANY MODEL

The present utility, with rare exceptions, is seen as a powerful and distant entity, whose aims are in most cases far apart from the real necessities of the common human being. Being powerful, it is seen as having an insatiable desire to maintain control and a lack of respect for minor achievements, or the possibility of achieving large events through the junction of various minor pieces. This seems to be mostly true not only in Brazil but all over the world, where the centralized utility model is being used. The fulfilling of these necessities has led to the present utility model that may be characterized by the following aspects:

- centralization
- huge and few power plants
- skyrocketing investment necessities
- closed community with a high "esprit de corps"

It seems that a new model will be necessary to cope with the challenges posed by the modern behavior of most societies and that it should follow a different path, one where closer contact with the community should be present. It looks like the new utility will have to offer a new series of services beyond electricity, it also would focus on a larger number of resources, instead of only a few. The importance of tight control would not occupy the first place in its priority list. All this would probably lead to a utility model as based on the following aspects

- decentralization
- smaller scale and larger number of generation units
- the existence of the "independent power producer" would be encouraged
- it (the utility) would use its assets, understood here in a broad sense, to promote the best use of the local and regional resources
- close interaction with the community
- use of smaller bunches of investments
- incentive for innovation as a high priority

- environmental concerns as a high priority

Although the above suggestions should be taken only as an initial approach to the issue, it seems to be a better utility model to cope with the challenges and desires of modern times. This closes this study which it is hoped will help to provide a better understanding of the energy issue in Brazil and particularly in the Northeast.

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