SOUTH KOREA THE BRAZILIAN ENERGY INITIATIVE BIOMASS CONTRIBUTION[1]

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ABSTRACT

As an effort to mitigate climate change and improve life quality in developing countries Brazil presented a proposal at the Johannesburg Conference on Sustainable Development. The proposal preparation was supported by technical documents and the one dealing with biomass as a source of energy is presented. The text discusses global biomass potential concluding that some particular energy crops are much superior than others. Sugarcane as a source of alcohol fuel and electricity has very favorable conditions as one of the leading crops due its high agricultural yield, the high conversion efficiency from primary to useful forms of energy, and the co-production of liquid fuel, heat, and electricity. It is shown that through the use of 300 million hectare of land it should be possible to fulfill all the global energy demand using the most advanced technologies in the agricultural and industrial processing phases. The document discusses several barriers and shows that economic feasibility, which has already been achieved in Brazil, is not enough to open a significant market. Other barriers, mainly the socio-economic ones, prevent the use of biomass energy sources. Considering the possibility that countries will be interested in the Brazilian Energy Initiative the text concludes with a list of practical actions that, if implemented, would allow most of the 102 sugarcane growers countries to rely on energy from sugarcane in the short-term.

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1. INTRODUCTION

For the WSSD Conference to be held in Johannesburg by August-September 2002 Brazil worked out a quantifiable proposal to mitigate climate change and improve sustainable development After several negotiations including, initially, Latin-American countries and, latter on, some OECD and other Developing countries the proposal was consolidated in a bracketed text PrepCom IV in Bali and included in the Chairman's Report (June 2002), which means it will be the object of further negotiations before or/at WSSD in Johannesburg.

> *[[Diversify energy supply by developing cleaner, more efficient and innovative fossil fuel technologies, and promote the] increase of the share of [non-hydro]/[new] renewable energy sources [by at least 2%]/[with the objective of increasing the global share to at least 15% of total primary energy supply by 2010.] [To achieve this all countries should adopt and implement ambitious national goals.][For industrialized countries, these goals should aim at an increase in the share of renewable energy sources of total primary energy supply by at least 2 percentage points of total energy supply by 2010 relative to 2000.]/[to at least 5% of total primary energy supply][by 2010].] at the goal level by 2010. To achieve this, all countries should adopt and implement specific national goals;]]*

For such specific proposal several background papers were prepared to quantify the world capacity to obtain from new and renewable energy sources a significant amount of energy by the year 2010. This text was prepared for such purpose and deals only with one of such sources – Biomass, and more specifically the issue of using alcohol in the transportation sector.

Traditionally, biomass has been used as a source of energy in all countries and its use has been associated with the degree of economic development of a country. Most of these uses involve non-commercial practices, satisfying poor people necessities, and consequently implying very low energy efficiency in the end-use process.

Nevertheless, some biomass have been used as a source of energy for commercial applications over the last three decades. With the necessity to compete with conventional sources, these new uses are carried-out with better transformation efficiency and involve modern technologies. The amount of commercial biomass in the total amount of all new and renewable energy sources is very significant (see Figure 1). Another evidence of the present importance of commercial biomass compared with other new and renewable sources may be seen in Table 1, which present global results for electricity generation.

Renewable biomass is presently the largest energy source in the "new and renewables" category and as such, in the short-term, has the largest potential to displace a significant amount of conventional energy sources.

2. PRESENT AND FUTURE POTENTIAL

Presently, the commercial biomass share in the primary world energy supply is around 1.7% of all energy sources (conventional, and new and renewables) and this record has been reached after 3 decades of use. This means that keeping the same pace of growth it may take more than a century, to reach 10% of the total world primary energy.

The interest in increasing its share in the energy market is tied to its future potential. Table 2 shows a recent evaluation of the technical potential of all new and renewable sources of energy and biomass has the largest potential after solar and wind.

It is worthwhile to comment that present world energy consumption is already higher than 300EJ/year and that by the year 2100 some estimates forecast consumption between 500 and 2700EJ/year. Such high level of consumption shows that some renewable sources (hydroelectricity and ocean energy) can make modest contribution and essentially, solar, wind and biomass have the possibility of occupying a significant share of the world primary energy portfolio in the year 2100.

The large participation of such three sources of energy is understood as a necessity if one of the aims of future generation is to stabilize CO_2 concentration in the atmosphere. Depending on the economic and social development of the world, the Inter – Governmental Panel on Climate Change (IPCC) concluded that Greenhouse Gas (GHG) emissions between 300 to 1500 GtC must be abated during this century. Options to mitigate GHG emissions are not restricted to the use of new and renewable sources of energy but they could make the largest contribution.

According to IPCC, in order to produce primary energy from new and renewable sources, at the level shown in Table 2, it will be necessary to use large extensions of land. Table 3 shows that the production of 440EJ/years of biomass energy demands 1280 million ha. Such extension of land is 3 to 4 times higher than the area required for wind and solar energy production and represents the total land areas of United States and Mexico together.

The first reaction to these numbers may be very negative; however, such huge extension of unused land is presently available and will also be available by the year 2050 when it is expected a peak in the earth population, as explained in Table 3. Another argument to justify the rationality for using such large extension of land is that the energy sector is very large since its revenue represents almost 10% of the world GNP. Hydroelectricity, which satisfy a little more than 2% of world primary energy demand (see Figure 1) already flooded an area of 40 Mha, usually the most productive ones since they are in the border of rivers. Also, it is worthwhile to note that several well credible energy scenarios are available showing that biomass energy can make contributions between 100 – 325EJ/year as shown in Table 4.

The land extension quoted in Table 3 is based on the wrong idea that wood plantations are the most efficient form of biomass energy. The next paragraphs of this section present other option and suggest a more modest land extension requirement to grow biomass for energy.

Figure 2 shows the area occupied by major crops in some countries and in the world. It is useful to learn that the largest crop area in a country is used for rice plantation in India with an extension of 41 million ha. It is possible to see that soybeans are an important crop in Brazil and USA, requiring 13 and 30 million ha, respectively. At world level the largest crop area is used for wheat production, which adds to 230 million ha. It is worthwhile to note that sugarcane crops, which are grown in 102 countries, mainly for production of sugar, use 23Mha at the world level (FAO, 2002).

Figure 3 presents the amount of biomass harvested from the major crops. It is visible that between all crops, sugarcane yields the largest amount of biomass in Brazil and India, and at world level, sugarcane (including top and leaves) yields 60% of the biomass matter harvested from all cereal crops together (FAO, 2002). This is a remarkable achievement: with only 23Mha of plantation it is possible to produce 1700Mt of biomass, while all cereal crops using more than 600Mha yields 2500Mt per year. Obviously, the purpose of cereal crops is food production, but it is noteworthy to remember that if energy will become a potential agricultural target, cereals are not the way to go.

Considering the very large potential of sugarcane as a source of energy, Table 5 and Table 6 present a simulation of a large plantation effort, which may be technically feasible by the year 2020 if the new and renewable energy market expands. Table 5 presents results for Brazil if the sugarcane crop area is expanded up to the same area presently occupied by soybean by the year 2020. Assuming that modern technologies will be used in all new plantations and in the processing of such biomass to liquid fuels and electricity, it is possible to produce an amount of 2.5Mboe/day of ethanol and 900TWh/year of electricity. Table 6 assumes that 143Mha would be committed for sugarcane energy crops by 2020 distributed in several countries. Under this scenario as much as 26Mboe/day of ethanol and 10,000TWh/year of electricity may be produced. Figure 4 compares these renewable energies sources with the total forecasted fuel and electricity demand by 2020. The result is impressive since such extension of crop (143 Mha) would generate more than half of the potential world energy requirement for electricity and one third of the global demand for fuel.

The major conclusion is that by using 300Mha (2 times the area used in Table 6), it should be possible to fulfill all the world energy demand of the year 2020 (around 400EJ). Consequently, The IPCC forecast presented in Table 3 is over estimated by a factor of 4. The reasons for that are:

a) Total energy availability from one ha of sugarcane crop is 980GJ/ha[3], instead of 400GJ/ha from forests;

[3] This is the value assumed for preparation of Tables 5 and 6 and should be achieved by 2020 if a significant effort is carried out. Presently, there are sugarcane commercial plantations where total aboveground biomass provides 1350GJ/ha (H. Ishitani et al, 1996).

b) From the same source of primary energy (sugarcane) it is possible to produce, through co-generation, liquid fuel and electricity, which improve conversion efficiency from primary to final energy sources[4].

3. TECHNOLOGIES ALONE ARE NOT ENOUGH

All the previous discussion only covers the technical aspect of how biomass can provide a significant share of the world energy needs. To transform such results in reality it is necessary to identify barriers other than technology and remove them in an effective way. Figure 5 shows how the technical, socio-economic, economic and market potential evolve with time and how they impose limits in the amount of any product or service offered. The highest potential is the technical one and through improvements in knowledge it can be pushed more towards the theoretical limit, known as thermodynamic potential. On the other hand, the lowest potential (market potential) is the one that reflects the real sales of a product or service. Even if a new product is cost-competitive with others well established products, in general, its market potential is below what could be sold based essentially in costs. Very often, old technologies survive because there are market distortions, like subsidies or costs associated with the old technology paid by the society and not by the product consumers.

3.1 Socio-economic issues

Once such market failures are removed sales may reach the economic potential. But good technology and good costs are not enough to displace well-established products from the market. The next level called socio-economic potential is associated with human behavior, covering attitudes and social barriers. An environmental safe product can be sold in the market by higher price than an environmental dangerous product if society recognizes and wants to pay to avoid the risks associated with poor environmental conditions. Table 7 lists some of the socio-economic barriers and the first one, lack of data, information, knowledge, and awareness, is being dealt with documents like this text.

Capital shortage, mainly to small companies, imposes unfair competition between conventional, and new and renewable energy producers. Figure 6 shows the well-known division of oil resources and reserves. Oil reserves, which are the source of most of the oil being used today, are relatively small compared with demand and well recognized that after the next 20 years they will be essentially available in a few countries, and probably extinguished in 40 years from now (Rogner et al, 2001). Nevertheless, the amount of resources is much larger than the reserves. Resources includes oil which, if produced today would be more expensive than reserves, as well as some oil that is probably economic but not yet well identified geographically.

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[4] Conversion of biomass to electricity is carried out with an efficiency of 20%, presently. With biomass gasification and gas turbines it should be possible to achieve 35%. In sugar mills a significant share of biomass is converted to electricity and heat with a total efficiency of 80%. Furthermore, conversion of sugar in ethanol has a very high efficiency.

With the large revenue from oil sales, oil companies, year after year, can develop new technologies that economically improve the competition of oil resources, as well as, locate new economic reservoirs, slowly transferring oil listed as resources to the category of reserves, and extending for, probably, a century the availability of oil in the market. On the other hand, most entrepreneurs dealing with new and renewable sources do not have financial resources to invest in R&D and have to pay high costs to borrow money in the market.

Attitudes, lifestyles and social values are other example of socio-economic barriers. A practical example is displayed in Figure 7. The figure shows the amount of emission from the four end-use-sectors of the economy as a function of time. Figures up to the year 2000 are from information collected while figures for the future years are constructed assuming that emission for each sector should evolve in the same rate as occurred in the last ten years. It is visible that emissions from the transport sector are growing much faster than for the other sectors (at an almost fixed rate of 2.5%/year for the last 3 decades) and probably will become as large as the industrial sector by the year 2020 (Moomaw et al, 2001). Since this rate of growth has been almost constant during the last 30 years with all the technical improvements carried out in automobile energy efficiency, it is very clear that only by changing human habits it should be possible to reduce society awareness for private transportation. Such changes of lifestyle are hard to implement and the problem could be more easily solved through technology. The proposal is to replace fossil fuel by renewable fuel (alcohol as an example). Thus, even keeping present human habits, the vehicle fleet would increase, but the amount of GHG emission from them would be reduced.

Sustainable Development is another example of values and attitudes of the society. Sustainable development, that has become an important issue in the last few years, has several definitions but we can think of it in terms of 10 major items (see Table 8). Sustainable development is not only a problem of the poor countries since it has interconnections with other global issues. One of them is Climate Change Mitigation as shown in Figures 8.

New and renewable sources of energy can make significant contribution for most of the 10 items associated with sustainable development. Biomass energy, in particular, has significant positive effects:

1. in clean air since GHG emissions are significantly reduced;
2. in energy availability since energy may be produced using mainly endogenous resources;
3. in land quality preservation since it may be used with less erosion (most energy crops are perennial)(Kartha and Larson, 2000);
4. in employment generation since it is strongly stimulated (biomass in general, and in particular sugarcane crop, is very intensive in rural manpower) and as a consequence of job creation positive impacts show up in transport, housing and health sectors (Kartha and Larson, 2000).

3.2 Economic issues

As already shown in Figure 5 it would be a major improvement in the sales of commercial biomass energy to increase its market potential to the level of the economic potential. The next few paragraphs are presented to demonstrate that at least for sugarcane crops, economic potential has been achieved or may be achieved very soon, based only in real costs evaluation.

Table 9 shows retail and wholesale sugar prices for several countries. It is noticeable the large range of prices. This is a consequence of the raw material used for sugar production (mainly sugarcane or sugarbeet), of the climatic condition in each country, and the degree of development of the sugar industry. Independent of such price range sugar is commercialized in the free international market by many countries, obviously at the same price. This paradox exists because subsidies are available in most of the developed countries to protect their farmers. This reduces competition of sugar producers located in tropical developing countries, the ones able to produce at the lowest cost since they rely on the high efficiency of sugarcane and in more favorable climatic conditions for agriculture. Sugarcane is grown in 102 countries and is a traditional culture, employing large amounts of rural people, and has essentially only two final commercial products – sugar and ethanol.

Figure 9 presents costs comparison for gasoline in United States and Brazil and for ethanol in Brazil in recent years. In USA gasoline refinery gate prices in 2000 were higher than 1999 due the increase in international oil price and ethanol should be priced at US$ 0.59 per gallon to be competitive with the 2000 gasoline price if used in cars powered by engines designed for gasoline. If the engine has a higher than usual compression ratio[5] then ethanol competitive price would be US$ 0.71/gallon. In Brazil, gasoline refinery price in 2001 was higher than in USA (oil price did not change too much from 2000 to 2001). Under this circumstance competitive ethanol prices are US$0.79 and 0.86/gallon, respectively for conventional and high compression engines. The figure also shows hidrated ethanol price (a blend of 96% per volume ethanol with water and suitable for neat ethanol cars) and anhydrous ethanol price (suitable for blend with gasoline) for Brazil in 2001. The conclusions are that ethanol (both kinds) competes economically with gasoline in Brazil, while in USA both kinds compete with gasoline in high compression engines but are a few percent more costly than gasoline when used in conventional engines. Two important remarks should be added. The first one is that gasoline production in USA has the lowest cost in the world due the volume and technology used. The second is that ethanol prices in 2001 in Brazil were good enough to generate profit to producers as demonstrated by the significant increase in production of sugarcane by the year 2002[6].

The price figures for ethanol in Brazil are the best in the world. This occurs because sugar and ethanol simultaneous production have a synergetic effect reducing costs, and Brazil has

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[5] Due its high-octane number neat ethanol cars can use higher compression engines and be more energy efficient than regular gasoline propelled engines

[6] Sugarcane yield is more sensitive to good care in the previous year than to climatic conditions at the harvesting year, and good care requires more investment from the producers.

produced over 200 million m3 of ethanol in the period 1975-2000. Figure 10 shows cumulative and annual ethanol production in the period 1975-1999 and Figure 11 shows the production cost decline as a function of the increase in production. An important point is that essentially all cost reduction may be attributed to the "learning-by- doing" effect since R&D financial resources were negligible in Brazil and in the world (developed and developing countries)(Criqui et al, 2000). Inclusion of advanced technology has a large potential to push down costs even further.

Finally, in the economic discussion it is worthwhile to add that commercial biomass energy production projects qualify for the Clean Development Mechanism (CDM) since GHG emissions will be reduced for most of these practices. In particular, when using sugarcane the energy balance is very favorable (the amount of fossil energy used in the production of sugarcane and its conversion to ethanol is several times lower than the energy value of ethanol) (Macedo, 1998) and the possibility to produce, simultaneously from the same agricultural product, liquid fuel and electricity has an even further impact in atmospheric C abatement, increasing the potential value added by commercialization of Carbon Emission Certificates. With this value added, it is possible to conclude that present ethanol prices in Brazil may be lower than gasoline prices at the refinery gate in USA (see Figure 9).

For the other 101 sugar producing countries growing sugarcane probably economic competition with gasoline may be difficult to achieve at this moment. Nevertheless, we should keep in mind the "learning-by-doing" lesson from Brazil. If this argument does not sound strong enough, let us present another one. Figure 12 shows international sugar price for the period 1960-1996 (one curve presents cost in historical dollar value and the other in constant dollars (US$ 1995)). We can see several price spikes, which last short periods, as well as the trend curve for constant US$ 1995. The trend is negative and sugar prices decline 19.5% per decade in the long time span analyzed. Figure 13 presents a plot for international gasoline prices (Rotterdam market) and the conclusion is that during the same time period the price moved upward. Since only sugar and ethanol can be produced in large amounts from sugarcane it is clear that ethanol price shall decline following the sugar path up to the point where sugarcane plantation will be vanished. This suggests the conclusion that if ethanol is not yet competitive with gasoline, it will become competitive not far in the future.

4. ACTIONS TO INCREASE COMMERCIAL BIOMASS USE IN THE ENERGY SECTOR

Based on all arguments presented, the following actions may be suggested:

- Immediately increase ethanol production by reducing exportation of molasses and its use as a feedstock for animals feeding. This action can be applied in around 150 sugar producer's countries. Associated with sugar production, molasses is always a by-product. At least an amount of molasses able to produce 15 liters of ethanol is available in the production of 100kg of sugar. From the production of 120Mt of sugar from sugarcane and sugarbeet it would be possible to produce 18 Mm^3/yr of ethanol. This means that it should be possible to produce ethanol sufficient to displace 0.7% of all fuels consumed in the world in few years.

- Immediately convert a share of sugarcane production from food to fuel. Such action can be carried out in 102 countries. Production cost for sugar will decline due the synergism discussed above. Present world sugar production from sugarcane is around 100 Mt/yr while the international market is around 30 Mt/yr. This means that reducing a few percent sugar production will increase international market price yielding a premium to sugar export countries (some of them developed countries). On the other hand, several sugar producers have large stocks that are not being commercialized due the risk of pushing even further down the price. Balancing all these aspects, a reasonable decision would be to divert 10% of sugarcane to ethanol production. This means 10Mt of sugar, yielding 7 million m^3/year of ethanol one or two years from the decision (this is the maximum time required to install industrial facilities; blending a few percent ethanol in gasoline is an easy task and can be initiated in a few months). Around 6 million m^3/yr equivalent of gasoline will be displaced representing 0.3% of the global fuel market (38 million boe/yr or 0.10Mboe/day while total fuel demand in world was 39 Mboe/day)

- Remaining countries without sugar or sugarcane production may have to import the product. International price for ethanol is not known. There is not yet such commodity market, but a few commercial operations already occurred. Considering that the only large-scale products derived from sugarcane and sugar beet crops are sugar and ethanol, there is no other reason than the increase in sugar price to increase ethanol international price. As already discussed in one of the preceding action, the idea is to reduce sugar production by only a 10% amount. Prices should be poorly affected. Assuming this scenario, probably less than half of the developing countries will need to import the product. Their demand (if 5% of the fuels will be supplied from renewable sources) may be around half the developing country demand –that is 2.5% of developing countries consumption of fuels or 250,000 boe/day. Importation of this product will displace importation of oil and oil derivatives. Assuming an overprice of 20% for renewable fuel compared with gasoline and a gasoline price of US$25/barrel the full extra cost for alcohol importing developing countries is at most US$1.25 million per day (US$450 million/yr). This extra cost should not be charged to developing countries and should be covered through some multilateral mechanism, like ODA on behalf of climate change mitigation.

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TABLE 1
RENEWABLE ELECTRICITY GRID-BASED GENERATION CAPACITY INSTALES AS OF 2000(MW)

Technology	All Countries	Developing Countries
Small hydropower	41000	25000
Biomass power	38000	30000
Wind power	18000	1700
Geothermal power	8500	3900
Solar thermal power	350	0
Total renewable power	105000	60000
Large hydropower	680000	260000
Total world electric power	3400000	1500000

Source: Martinot et al, 2002

TABLE 2
LONG TERM TECHNICAL POTENTIAL - RENEWABLE ENERGY SUPPLY

	Long-term Technical Potential (EJ/yr)
Hydro	>50
Geothermal	>20
Wind	>630
Ocean	>20
Solar	>1600
Biomass	>440
Total Renewable	>2800

2100 Total Energy Demand for SRES scenario ranges 515-2737 EJ/yr

Source: Moomaw et al, 2001

TABLE 3
AMOUNT OF LAND REQUIRED FOR ALTERNATIVE ENERGY PRODUCTION
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WIND	300 (1)
SOLAR ENERGY	393 (2)
BIOMASS	1280 (3)

1) 10% of all earth land area with wind speed above 5.1 m/s at 10m height
2) 10% of the land area classified as “other lands” category by the FAO(1999)
3) All potential crop land area not been required for food crops in year 2050 are used

Source: Moomaw et al, 2001

TABLE 4 - POTENTIAL CONTRIBUTION OF BIOMASS TO THE WORLD'S ENERGY NEEDS

Source	Time frame (year)	Total projected global energy demand (exajoules a year)	Contribution of biomass to energy demand (exajoules a year)	Comments
Riges (Johansson and others, 1993)	2025 2050	395 561	145 206	Based on calculation with the RIGES model
SHELL **(Kassler, 1994)**	2060	1,500 900	220 200	Sustained growth scenario Dematerialization scenario
WEC (1994[a])	2050 2100	671 – 1,057 895 – 1,880	94 – 157 132 –215	Range given here reflects the outcomes of three scenarios
Greenpeace and SEI (Lazarus and others, 1993)	2050 2100	610 986	114 181	A scenario in which fossil fuels are phased out during the 21[st] century
IPCC	2050	560	280	Biomass intensive energy system development
(Ishitani and Johansson, 1996)	2100	710	325	

Source: Turkenburg et al, 2001

TABLE 5 – ENERGY PRODUCTION FROM SUGARCANE PLANTATION – AREA EQUIVALENT TO SOYBEANS CROP – BRAZIL 2002/2020

YEAR	AREA	YIELD	TOTAL PRODUCTION	ENERGY PRODUCTION Fuel		ENERGY PRODUCTION Electricity		TOTAL ENERGY Fuel+Elec.	
	(Mha)	(t/ha)	(Mt/yr)	(EJ)	(Mboe/day)	(TWh/yr)	(EJ)	(EJ)	(Mboe/day)
2003	2,60	70	182	0,429	0,239	9,1	0,064	0,492	0,274
2004	2,86	74	210	0,495	0,276	11,6	0,081	0,576	0,321
2005	3,15	77	243	0,572	0,318	26,7	0,187	0,759	0,422
2006	3,46	81	280	0,661	0,368	46,3	0,324	0,985	0,548
2007	3,81	85	324	0,763	0,425	71,3	0,499	1,262	0,702
2008	4,19	89	374	0,881	0,490	102,9	0,720	1,601	0,891
2009	4,61	94	432	1,018	0,566	142,6	0,998	2,016	1,122
2010	5,07	98	499	1,176	0,654	192,1	1,345	2,521	1,402
2011	5,57	103	576	1,358	0,756	253,6	1,775	3,133	1,743
2012	6,13	109	666	1,568	0,873	329,5	2,307	3,875	2,156
2013	6,74	114,02	769	1,811	1,008	422,9	2,960	4,772	2,655
2014	7,42	120	888	2,092	1,164	444,1	3,108	5,201	2,894
2015	8,16	126	1026	2,417	1,345	512,9	3,590	6,007	3,342
2016	8,98	132	1185	2,791	1,553	592,4	4,147	6,938	3,860
2017	9,87	139	1368	3,224	1,794	684,2	4,789	8,013	4,458
2018	10,86	140	1521	3,582	1,993	760,3	5,322	8,904	4,954
2019	11,95	140	1673	3,940	2,192	836,3	5,854	9,794	5,449
2020	13,14	140	1840	4,334	2,412	919,9	6,439	10,774	5,994
Increase	5,05	2	10,11	10,109	10,109	101,1	101,089	21,878	21,878
TOTAL 2000*					39	13000			
TOTAL 2020*					68	22000			

Source: Author

TABLE 6 – WORLD FEASIBLE SUGARCANE PLANTATION LARGE EFFORT SCENARIO- 2020

COUNTRY	POTENTIAL	FUEL		ELECTRICITY		FUEL+ELECTR.	
				PRODUCTION		PRODUCTION	
	AREA (Mha)	(EJ)	(Mboe/day)	(TWh/yr)	(EJ)	(EJ)	(Mboe/day)
BRAZIL	20	6,60	3,67	1400	9,8	16,40	9,12
USA	10	3,30	1,84	700	4,9	8,20	4,56
INDIA	10	3,30	1,84	700	4,9	8,20	4,56
CHINA	10	3,30	1,84	700	4,9	8,20	4,56
MEXICO	4,8	1,58	0,88	336	2,35	3,94	2,19
CENTRAL AM	4,8	1,58	0,88	336	2,35	3,94	2,19
SOUTH AM	16	5,28	2,94	1120	7,84	13,12	7,30
SOUTH ASIA	16	5,28	2,94	1120	7,84	13,12	7,30
AUSTRALIA	16	5,28	2,94	1120	7,84	13,12	7,30
AFRICA	16	5,28	2,94	1120	7,84	13,12	7,30
OTHER	20	6,60	3,67	1400	9,8	16,40	9,12
TOTAL	143,6	47,36	26,35	10052	70,4	117,72	65,50
PRESENT AND FUTURE WORLD OIL AND ELECTRICITY DEMAND							
TOTAL 2000*			39	13000			
TOTAL 2020*			68	22000			
* Source: US-EIA, International Energy Outlook							

Source: Author

TABLE 7 - WHAT ARE THE MAIN BARRIERS TO REACH THE SOCIO-ECONOMIC POTENTIAL?

- Data, information, knowledge, awareness
- Access to capital, especially smaller firms
- Risk aversion in financial institutions, including MDB's
- Trade barriers such as tariffs or export restrictions
- Human and institutional capabilities
- Missing codes and standards for EST's
- Low, subsidised conventional energy prices
- Absence of full-cost pricing
- Individual preferences/ lifestyle
- Poverty

Source: Sathaye et al, 2001

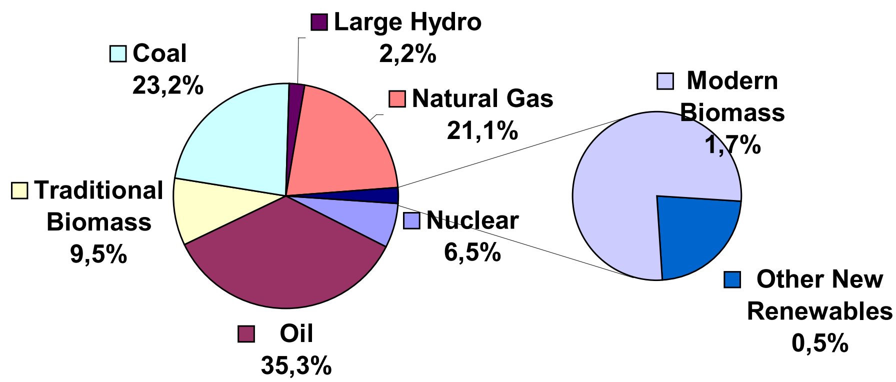
TABLE 8 – WHAT IS SUSTAINABLY DEVELOPMENT?	
• Many definitions but can usefully think of SD in terms of 10 challenges:	
Clean air	Transportation
Clean water	Housing
Food	Jobs
Energy	Waste disposal
Land use	Health care
• Key is integration across all three domains of SD: social, economic and environmental	

Source: Banuri et al, 2001

TABLE 9 – SUGAR PRICES IN THE LEADING SUGAR TRADING NATIONS NET EXPORTERS NET IMPORTERS (U.S. cents per pound of white sugar)					
	Retail	**Wholesale**		**Retail**	**Wholesale**
Brazil	15		**Russia**	33	22
Australia	35		**United States**	43	27
EU	60		**Japan**	73	48
Cuba	8		**South Korea**		36
Thailand	13	12	**Canada**	30	16
Guatemala		22	**Malaysia**	18	17
South Africa		22	**Egypt**	21	18
Colombia		27	**Mexico**	23	21

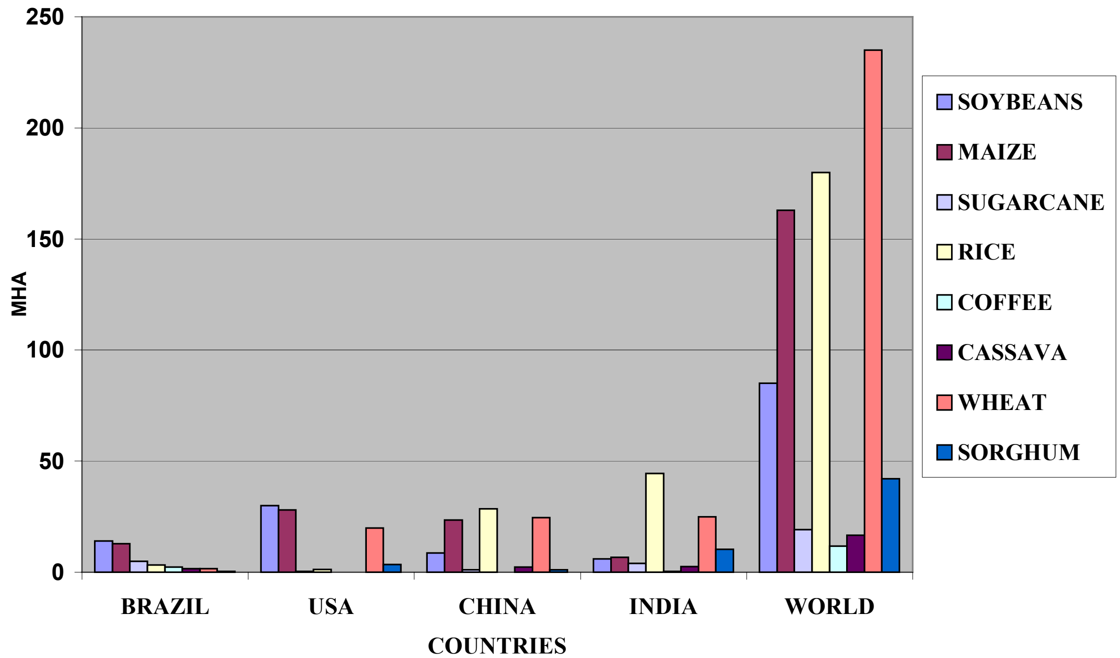
Sources: Haley, 1998; Licht, 1999

FIGURE 1 - WORLD CONSUMPTION OF PRIMARY ENERGY AND RENEWABLES, BY ENERGY TYPE, 1998



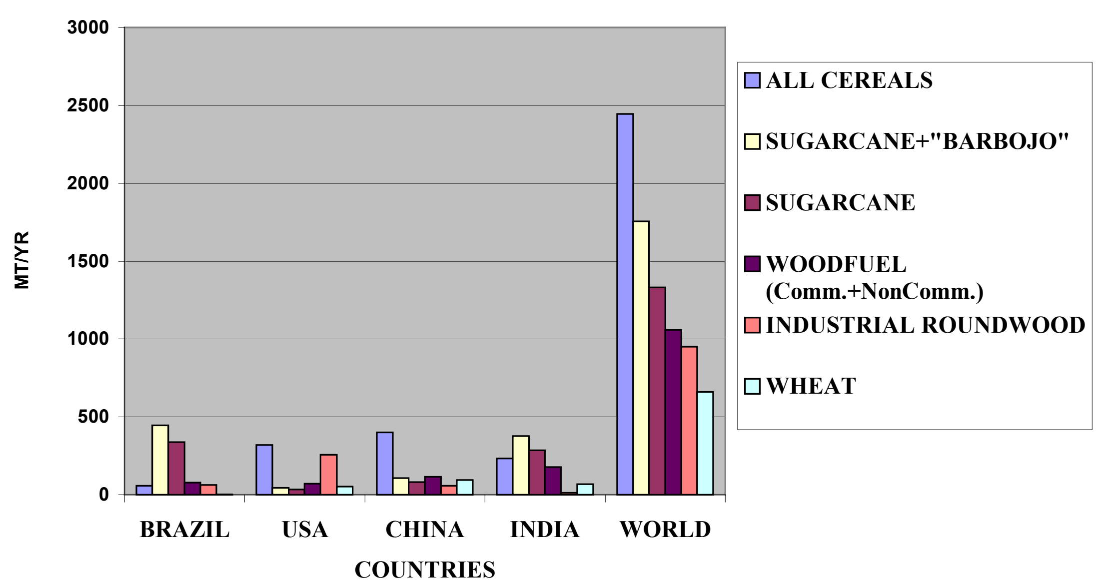
Source: WEA, 2001

FIGURE 2
HARVESTED AREAS FOR SOME MAJOR CROPS



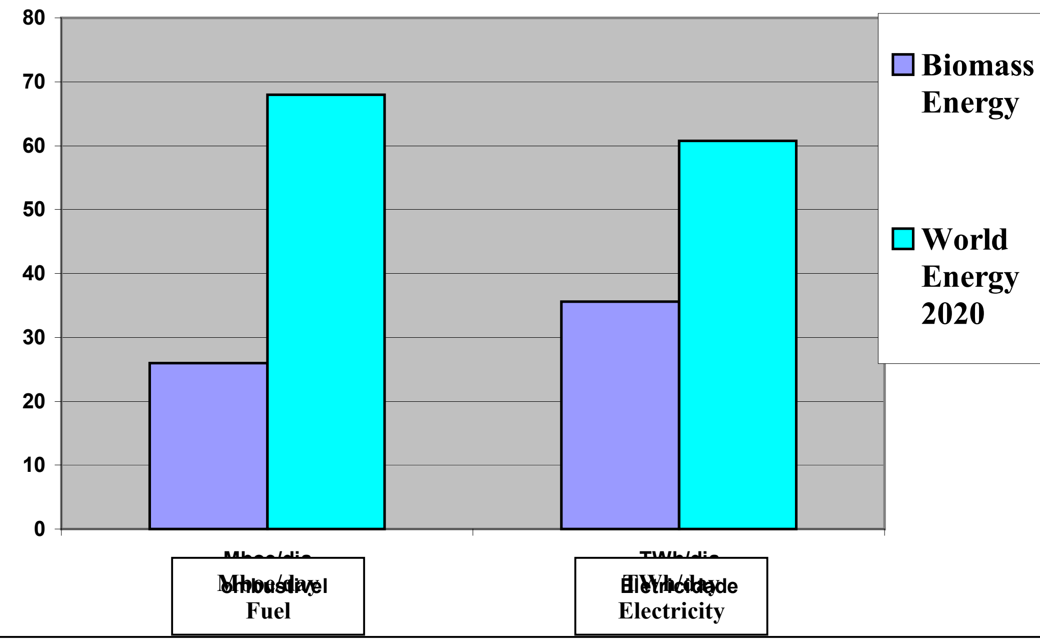
Source: FAO, 2002

FIGURE 3
AMOUNT OF BIOMASS HARVESTED- MAJOR CATEGORIES- 2001



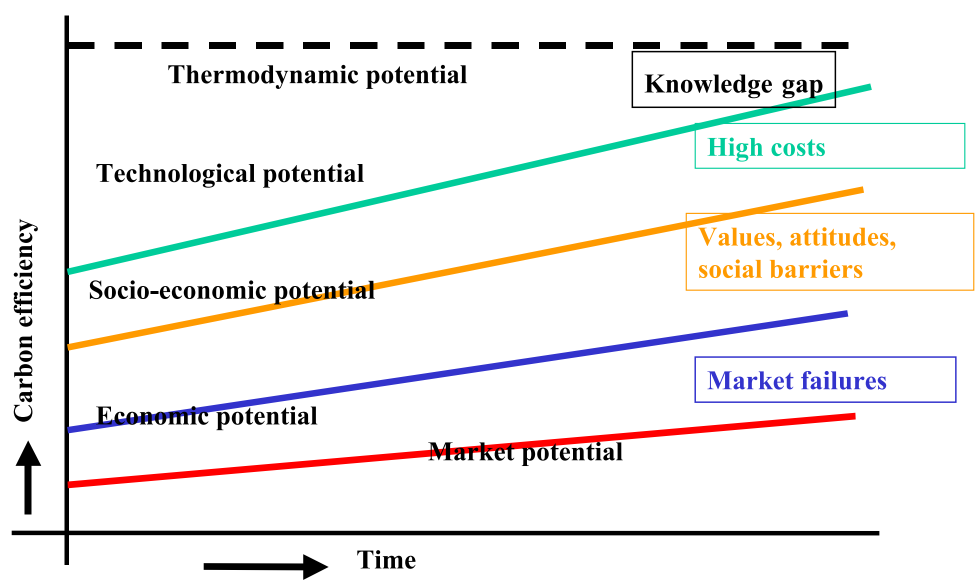
Source: FAO, 2002

FIGURE 4 - POTENTIAL CONTRIBUTION OF BIOMASS - SUGARCANE - 145 MILLION/HA - 2020 SCENARIO



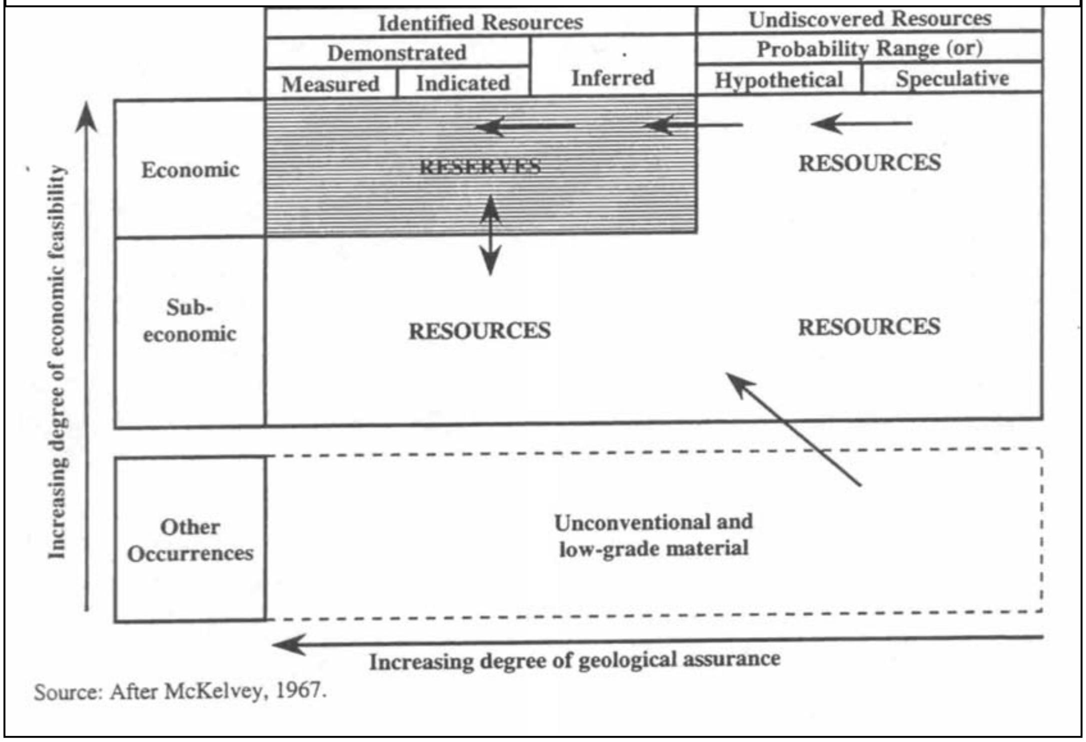
Source: Author

FIGURE 5
BARRIERS TO ACHIEVING THE POTENTIAL OF TECHNOLOGIES



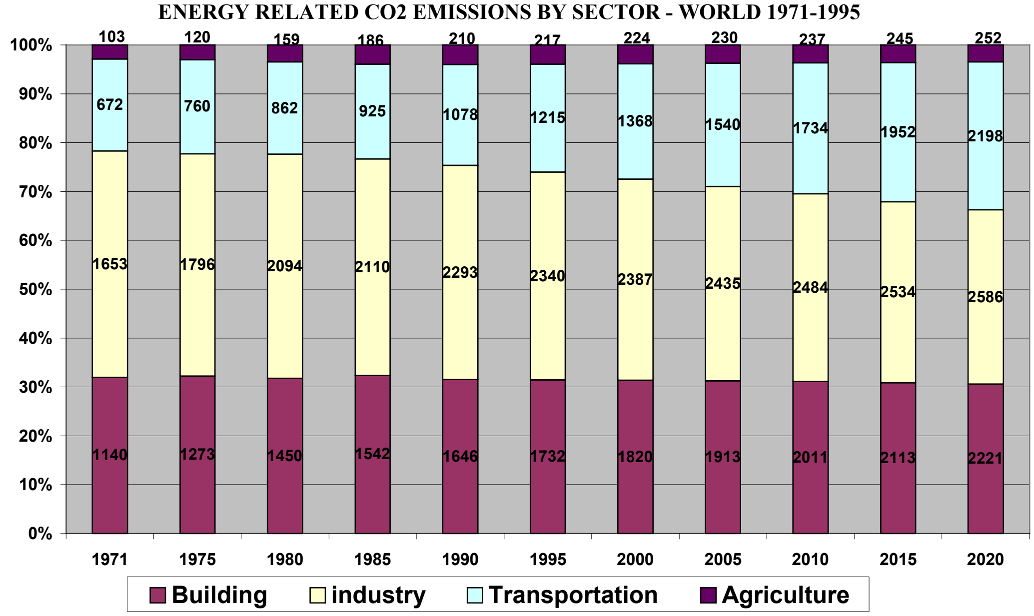
Source: IPCC, 2001

FIGURE 6 – PRINCIPLES OF RESOURCE CLASSIFICATION



Source: Rogner et al, 2001

FIGURE 7
ENERGY RELATED CO2 EMISSIONS BY SECTOR - WORLD 1971-1995



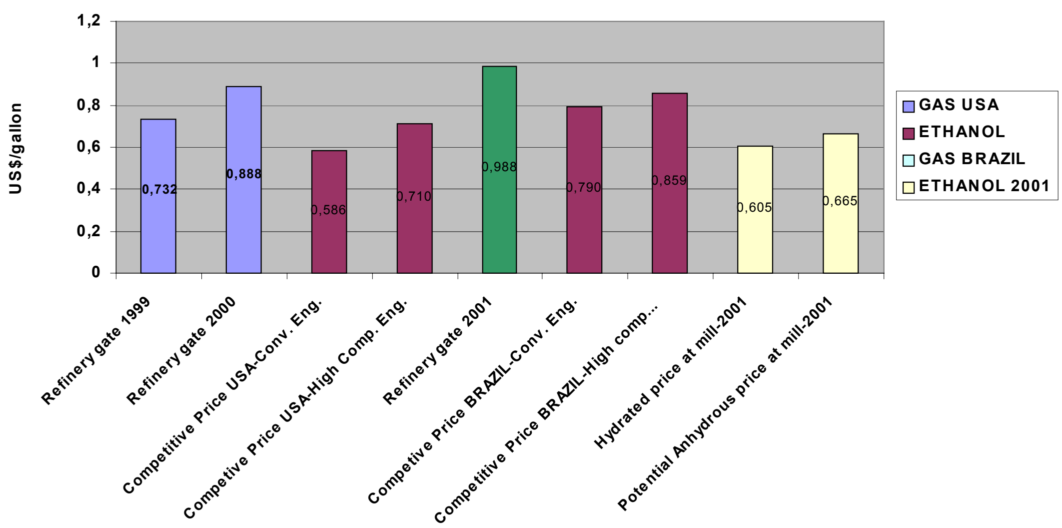
Source: Moomaw et al, 2001; extrapolation to 2020 by author

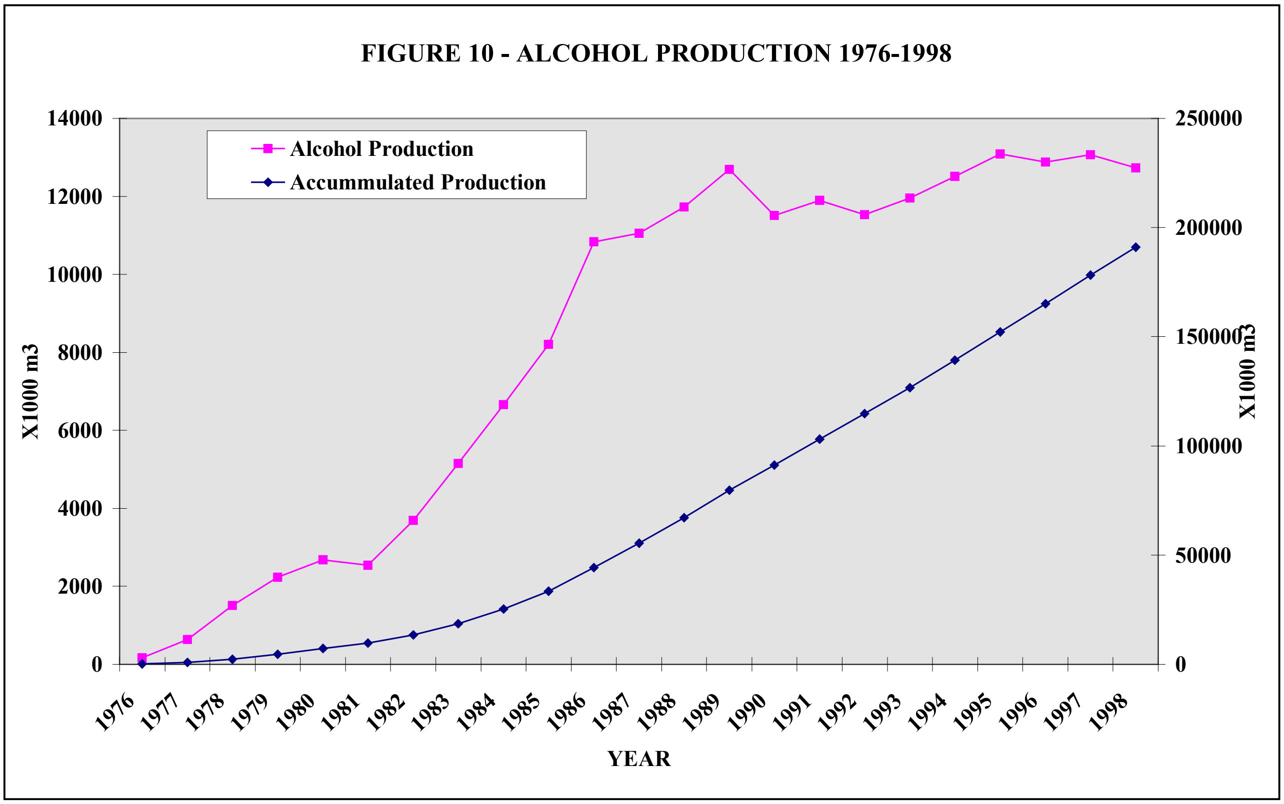
FIGURE 8
WHY CONSIDER SUSTAINABLE DEVELOPMENT (SD) IN TAR?

- SD and climate change mitigation (CCM) are linked
  - SD policies may affect emissions and mitigative capacity
  - CCM affects SD prospects
- SAR pointed to connections but didn't explore them in detail
- Cross-cutting paper on development, equity and sustainability produced

Source: Banuri et al, 2001

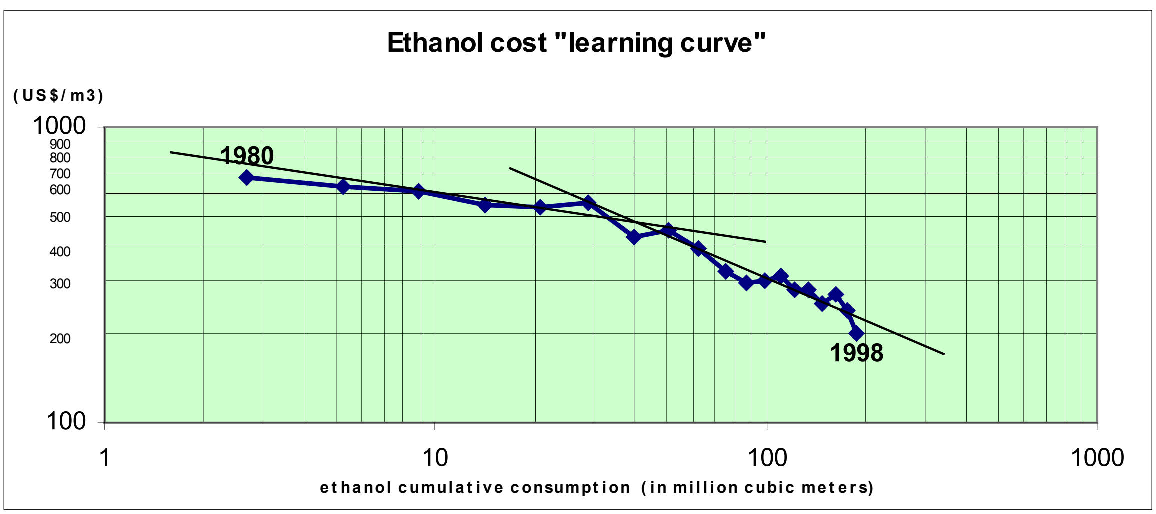
FIGURE 9 – GASOLINE PRICES IN USA AND BRAZIL, AND ETHANOL PRICES IN BRAZIL



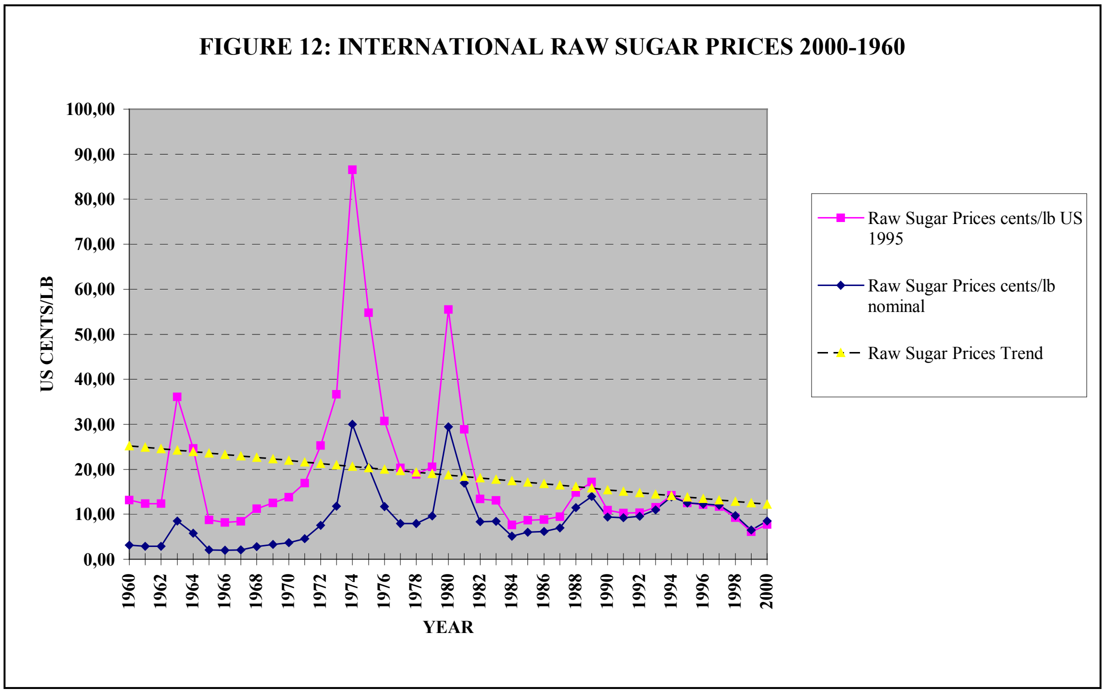


Source: Author

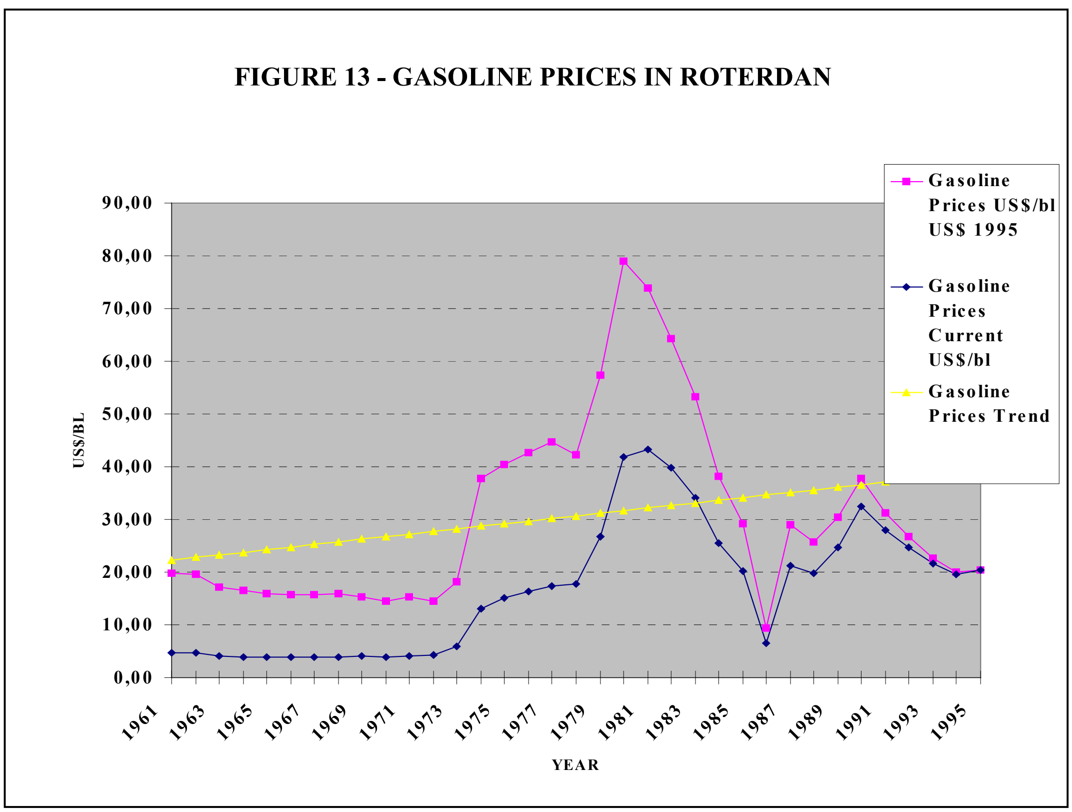
FIGURE 11



Source: Goldemberg, 2000



Source: Moreira and Goldemberg, 1999



Source: Moreira and Goldemberg, 1999