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Biofuels in Brazil

Life Cycle Avoided CO2 Emission

Comparison of Sugar Cane Ethanol with Corn Ethanol

Relationships with Food and Deforestation

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World Energy and Fossil Fuel Consumption

Biofuels substitution for fossil fuel became a very important issue nowadays for several reasons:

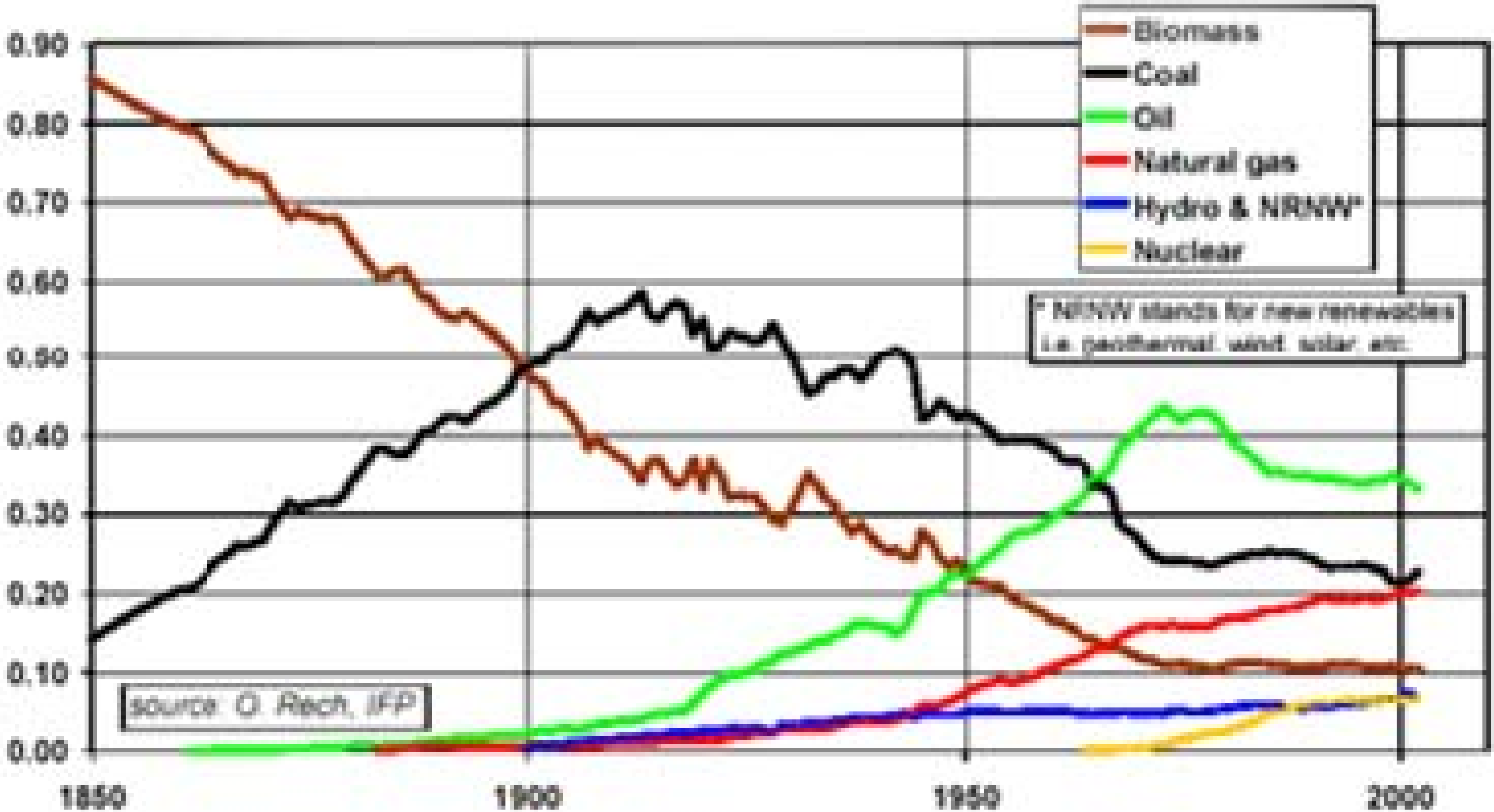
(a) the increasing price of oil barrel and the limits of oil resources in the World;

(b) the increase of fossil fuels consumption in developing countries, in particular in China due to its very high economic growth;

(c) the environmental constraints, mainly the problem of GHG emissions and climate change;

(d) the challenges of sustainable development and elimination of extreme poverty in developing countries;

(e) the possible impacts of biofuels on crops for food supply and on deforestation.


Biomass
Coal
Oil
Natural gas
Hydro & NRNW*
Nuclear
* NRNW stands for new renewables i.e. geothermal, wind, solar, etc.
source: O. Rech, IFP
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1850
1900
1950
2000

GHG Emissions and
the Dominant Role of CO_2

- According to IPCC Forth Assessment Report [IPCC, 2007], the world GHG emissions did grow up 70% from 1970 until 2004.

- Among them, CO_2 emissions have increased 80% and they were 77% of GHG anthropogenic emissions in 2004.

- So, CO_2 remains as the main GHG from anthropogenic sources.

Growth of GHG emissions from 1970 until 2005

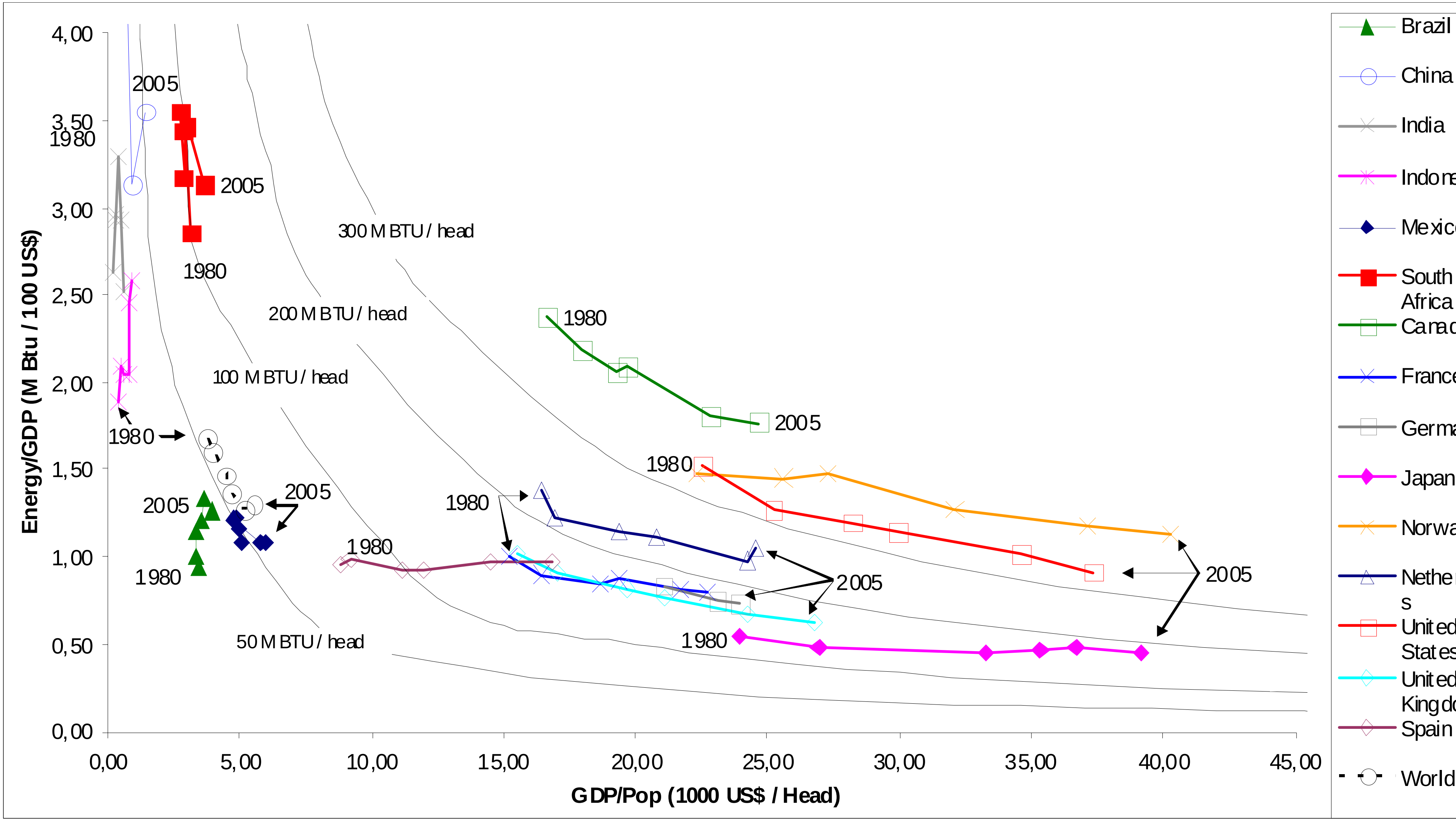
- electric energy system with 145%,
- transportation with 120%,
- industry with 65% and
- change of land uses and deforestation with 40%.

Present situation in the World:

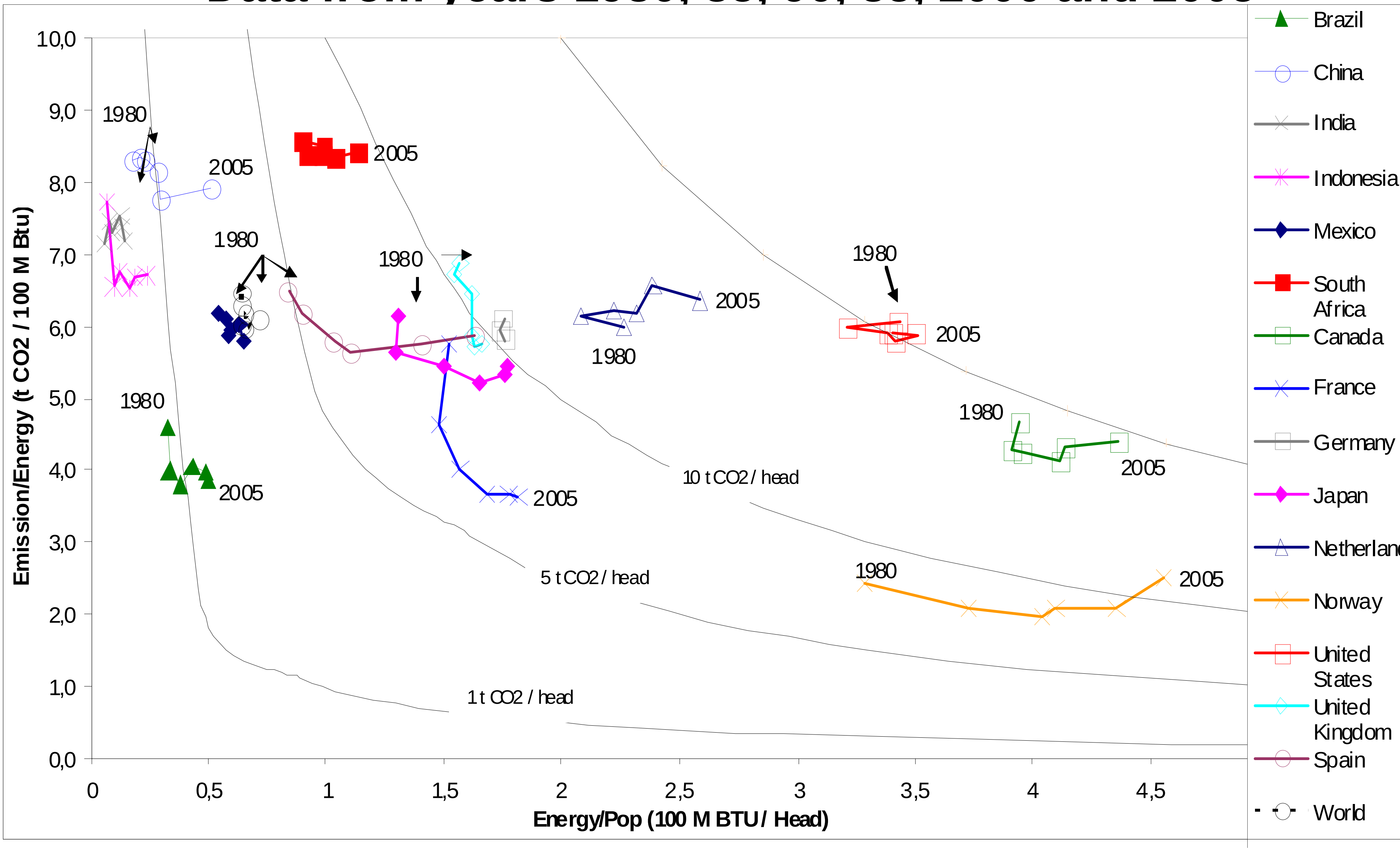
(1) Developed countries have not reduced up to now their emissions in such a way to reach the goals of the Kyoto Protocol, whose period of commitment did already start in 2008 and it will end in 2012;

(2) Developing countries tend to increase their emission with the economy growth as they follow developed countries consumption pattern.

Energy per Capita (E / Pop = E / GDP x GDP / Pop)
Data from years 1980, 85, 90, 2000 and 2005



CO2 Emissions per Capita from Energy (CO2/Pop = E/Pop x CO2/E) Data from years 1980, 85, 90, 85, 2000 and 2005



Energy Consumption in Transport in Brazil in 2007

Mllions of tons equivalent of oil (Mtoe)

- Diesel 28.83 → 10 Mtoe – public transport
- Gasoline 13.87 ↘ 22.49 Mtoe – private cars
- Ethanol 8.62 ↗ ↓
- Others* 5.58 1/8 population

* Includes fuel oil, aviation querosene, natural gas and electricity

Biofuels in Brazil and
The Dominant Role of Ethanol

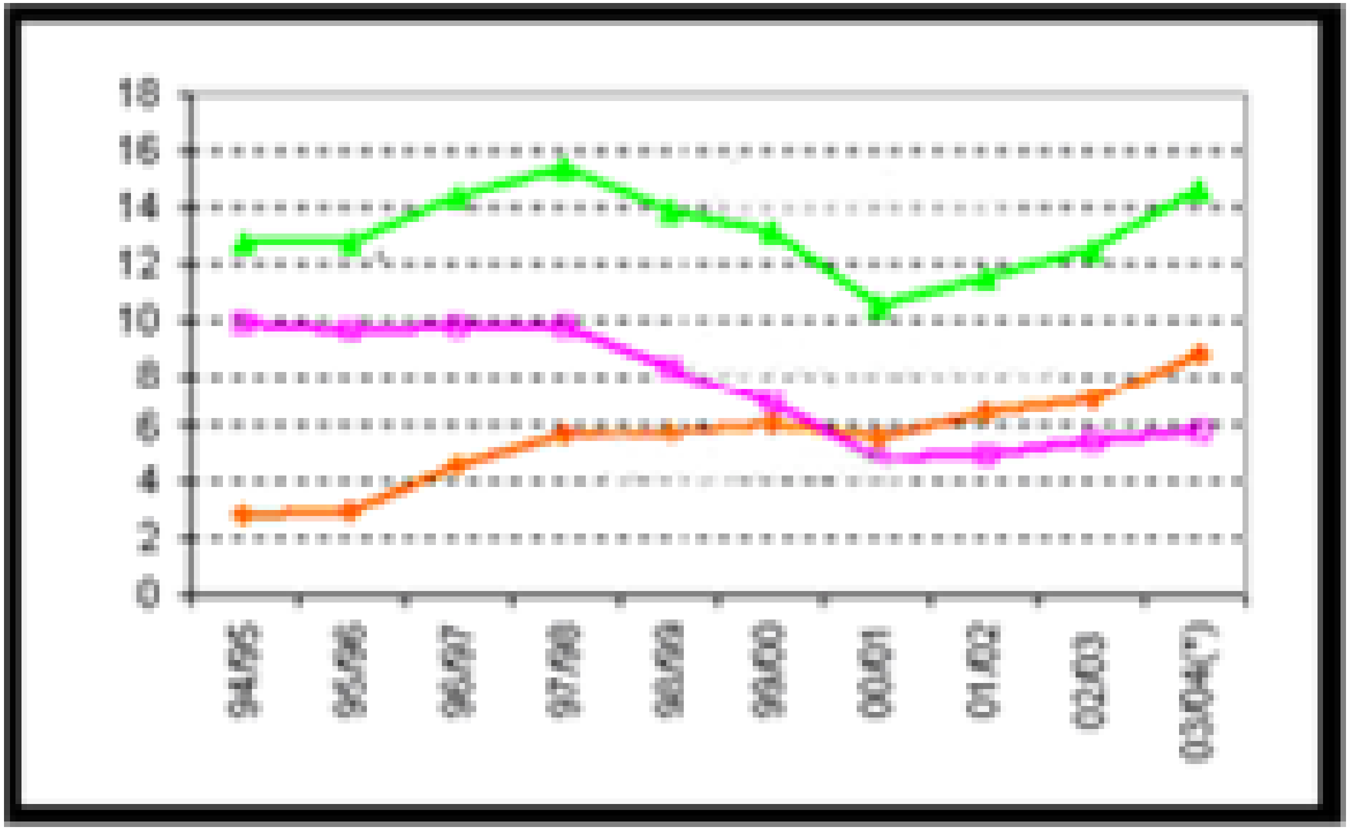
Uses of Bioenergy in Brazil

Technology	Biomass Raw Material	Products	Main Use	Fossil Fuels Substitution
Direct Combustion	Firewood Sugar cane bagasse and trash and other wastes #	Heat	Cooking Industry Electric power	LPG Fuel oil Natural gas
Bioconversion:				
- Fermentation	Sugar cane	Ethanol	Transport	Gasoline*
- Anaerobic digestion	Wastes	Biogas	Potential	Natural gas
Chemical and Thermal:				
- Pyrolysis	Wood	Charcoal	Industry	Coal and fuel oil
-Gasification	Biomass	Synthesis gas	Industry	Natural gas
-Esterification	Vegetable oil and others materials**	Biodiesel	Transport	Diesel
- Cracking	Vegetable oil	Diesel	R&D	Diesel
- Hbio***	Vegetable oil	Diesel	Pilot	Diesel
Hydrolysis (2d generation)	Biomass	Ethanol	R&D	Gasoline*

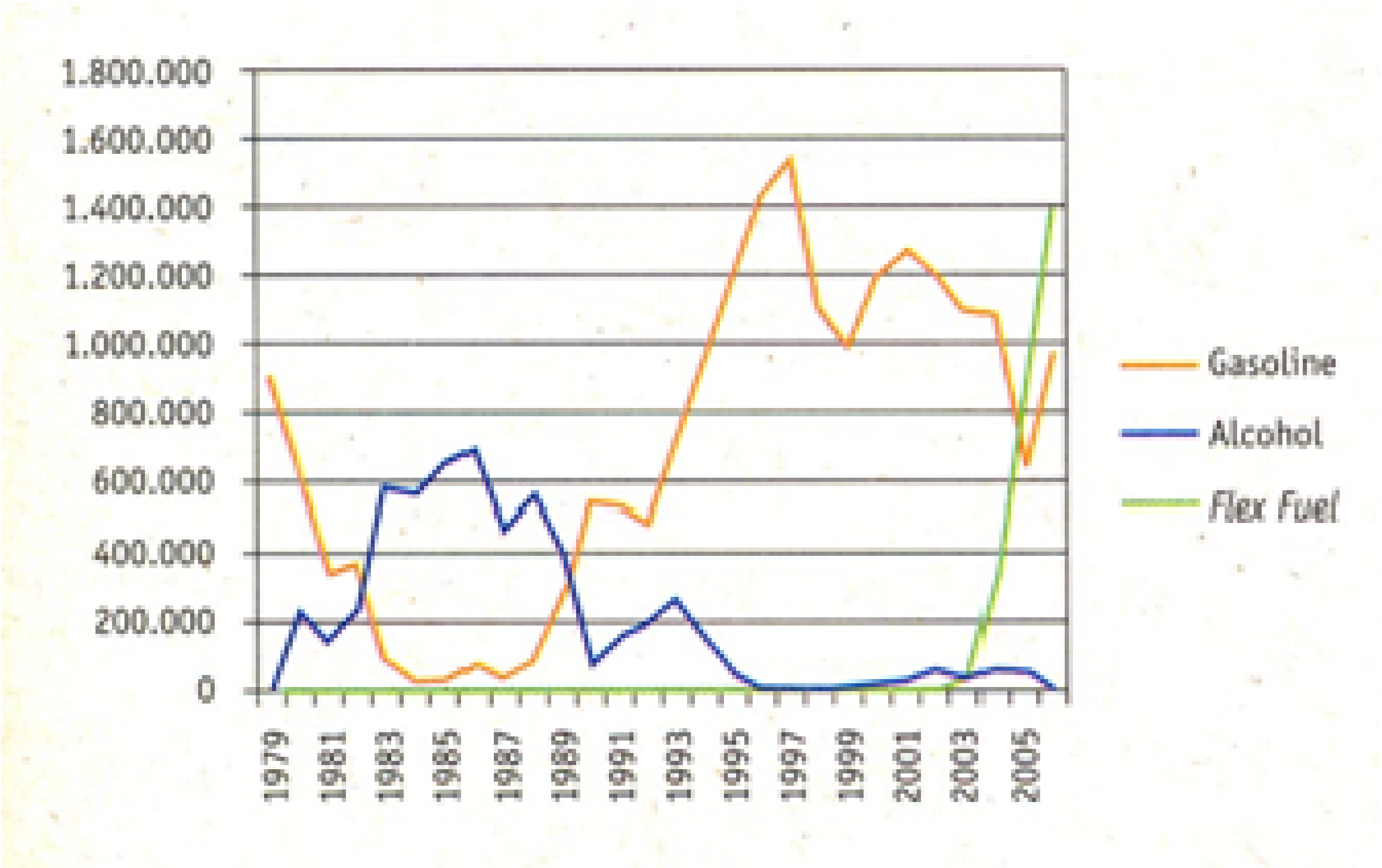
Ethanol Fuel in Brazil

- The Brazilian Alcohol Program started in 1975 after the first oil shock and it did consist of using ethanol as additive to gasoline in a first phase.
- After the second oil shock in 1979, there was a second phase, with ethanol as substitute for gasoline in cars, whose Otto cycle engines were adapted for this purpose.
- By 1985 more than 90% of new cars sales were of ethanol fuelled cars.
- In the 1990 decade there was a shortage of ethanol in the Country. The result was the lack of consumer confidence in ethanol, with the consequent reduction of sales of new cars with ethanol fuelled engine to 11% in 1990, 2% in 1995 and 1% in 2000.
- After the year 2003 a renewal of ethanol has happened because of flex fuel car production in Brazil. Those cars, which can be fuelled with two different fuels in any proportion,

Evolution of ethanol consumption in Brazil (billions liters a year)
Green = total; orange = as additive to gasoline and
pink = pure ethanol engines and flex cars



Sales of Gasoline, Alcohol and Flex Cars in Brazil



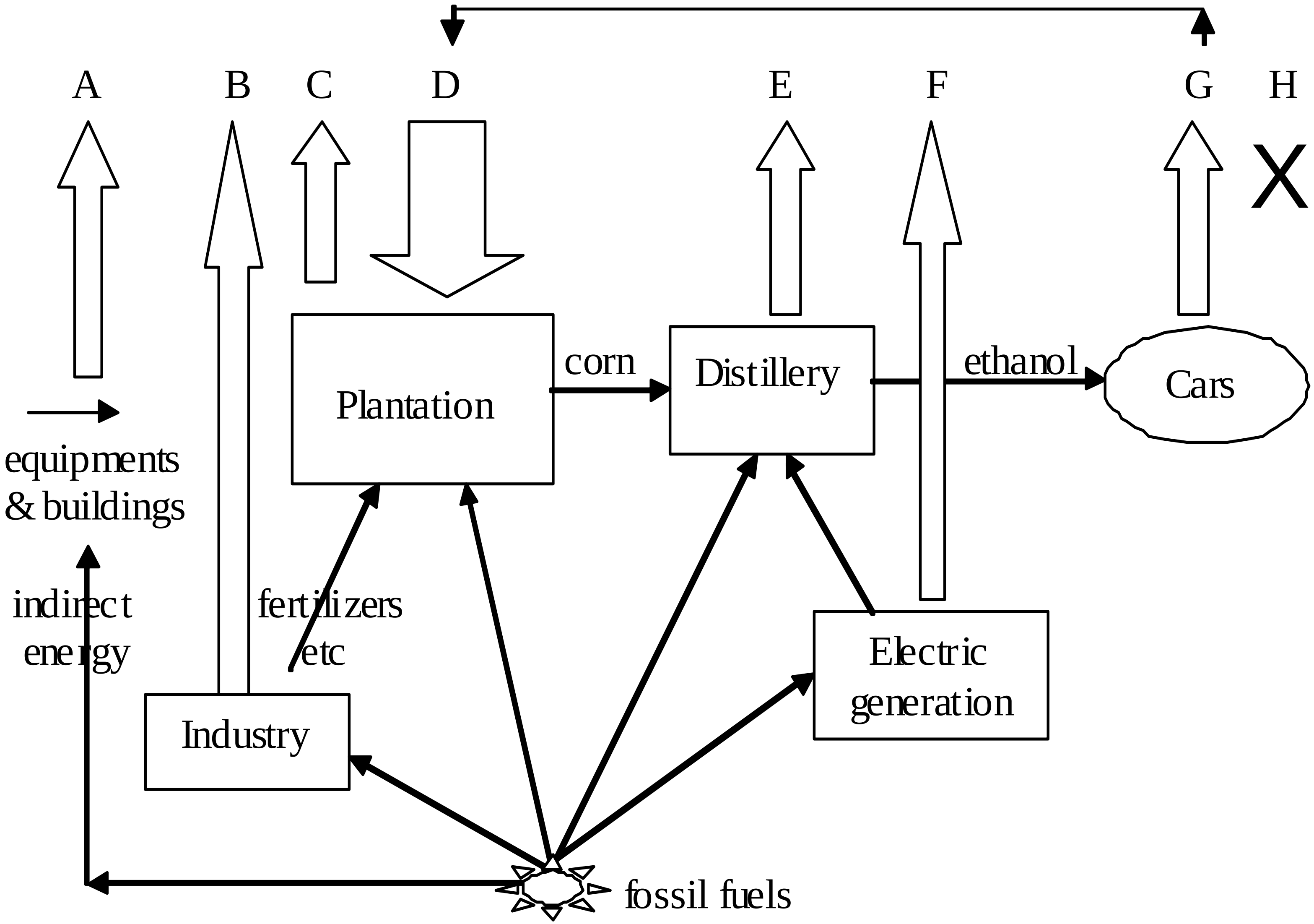
Comparison of Sugar Cane Ethanol with Corn Ethanol

	US corn	Brazil sugar cane
Percentage of World production	54%	33%
Area that is occupied	35 Mha	7 Mha

GHG missions in corn ethanol production and avoided CO2

Balance of CO2 capture by corn: D = G (1)

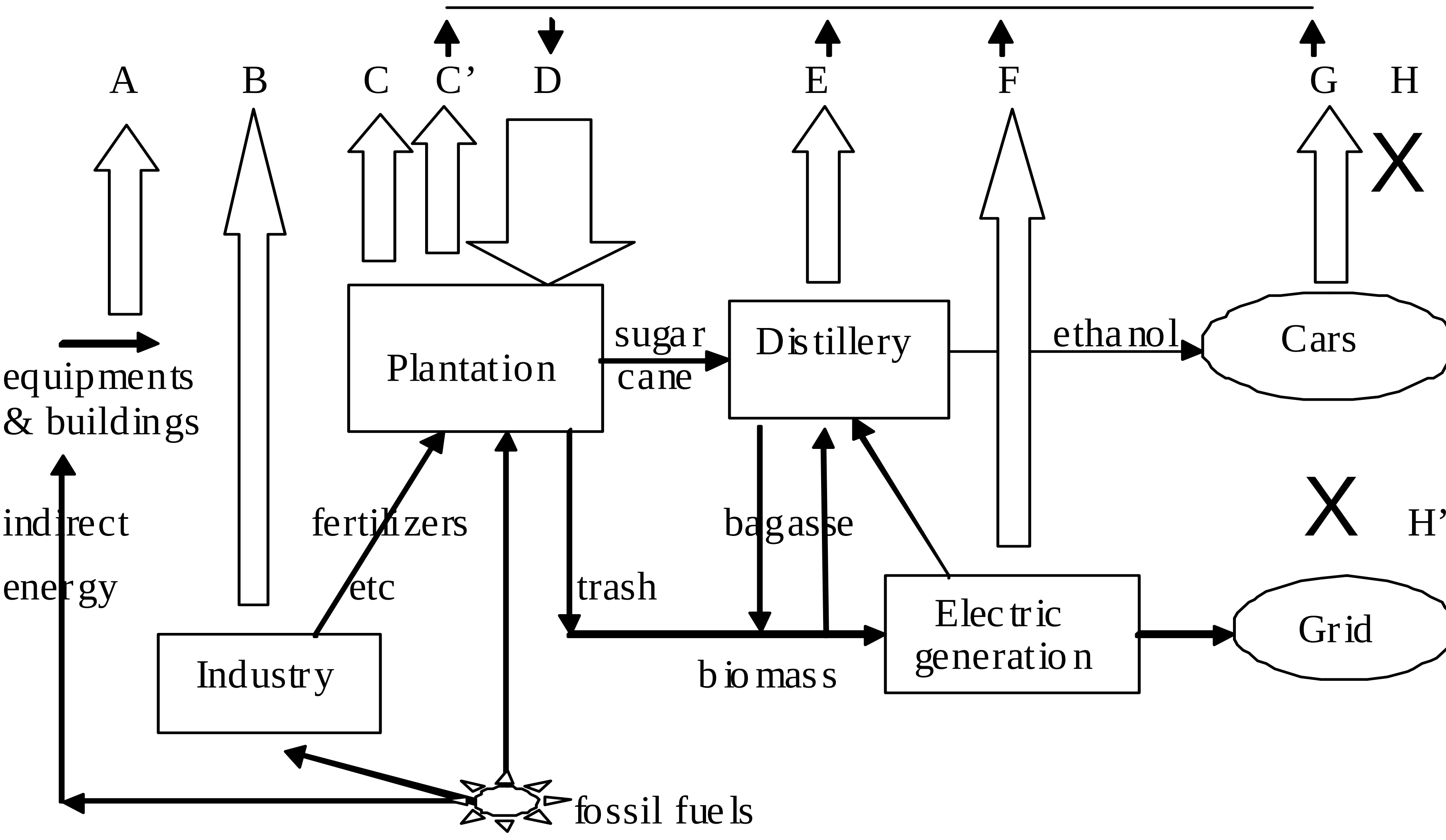
Net avoided CO2 by corn ethanol = H – A – B - C – E - F (2)



GHG missions in sugar cane ethanol production and avoided CO2

Balance of CO2 capture by sugar cane: D = C’+ E + F + G (3)

Net avoided CO2 by sugar cane ethanol = H + H’ – A – B - C (4)



GHG Emissions in Sugar Cane Ethanol Production

(Percentages of CO2 equivalent)

Source of emission	Kind of emission	%
From life cycle (A): equipments, buildings, etc	in cane production	6.6
	in ethanol production	9.5
From fertilizers, etc (B)	in cane production	20.6
From sugar cane burning before harvest (C)	CH_4	19.1
	N_2O	18.2
From soil (C)	N_2O	6.9
From fossil fuel consumption (C)	CO_2	19.1
Adding up (according figure 10)	A	16.1
	B	20.6
	C	63.3

Source: Elaborated by using data from [Macedo, Leal and Ramos da Silva, 2004]

Net avoided CO_2 in terms of percentage of fossil fuel CO_2 emission:

Sugar cane ethanol

$$P = 1 - (A + B + C) / (H + H') \qquad (6)$$

Corn ethanol

$$P = 1 - (A + B + C + E + F) / H \qquad (7)$$

Sugar cane ethanol relative to gasoline

$$P' = 1 - (A + B + C - H') / H \qquad (8)$$

Energy gain, GHG emissions and percentage of CO_2 that is avoided by ethanol industry in Brazil

Results from 2002/2003 Harvest	Average	Best Value Scenario
Energy consumption EC (Mcal/t cane)		
Sugar cane agriculture	48.2	45.8
Ethanol production	11.8	9.5
Total	60.0	55.3
Energy production EP (Mcal/t cane) (ethanol + electric energy from bagasse surplus)	499.4	565.7
Energy gain (EP/EC)	8.3	10.2
GHG emissions (kg CO_2 equiv. / t cane)		
From fossil fuel consumption	19.2	17.7
Others	15.3	15.3
Total	34.5	33.0
Total GHG emission (kg CO_2 equiv./ m3 of ethanol) (A+B+C in figure 10)	405.8	358.7
Net avoided CO_2 (kg CO_2 / m3 of ethanol) from gasoline and fuel oil for electric energy H+H'- (A+B+C) in figure 10		
For anhydrous ethanol	2600	2700
For hydrated ethanol	1700	1900
Percentage of CO_2 that is avoided (formula 6)		
For anhydrous ethanol	86%	88%
For hydrated ethanol	81%	84%

Source: Elaborated by using data from [Macedo, Leal and Ramos da Silva, 2004]

The Energy Potential of Sugar Cane

Energy from 1 Metric Ton of Sugar Cane Considering Heat Values

	Mcal/t of cane
92 litters of ethanol (best value)	478
280 kg of bagasse with 50% of humidity	596
280 kg of trash with 50% of humidity	596

Source: Braunbeck, Macedo and Cortez in [Silveira, 2005]

Large part of energy potential of sugar cane is not utilized

Most of bagasse is used with very low efficiency

Trash is burned to allow manual harvesting

Energy from 1 Metric Ton of Sugar Cane

Mcal per ton of cane

	Brazil 2006	Future Scenario	Variation
Ethanol (energy of gasoline replaced)	460*	559**	21%
Bagasse for electric energy (part to grid)	68	214***	314%
Trash for electric energy (all to grid)		298 ****	infinitive
Total	528	1071	102%

* Considering 75.7 liters of ethanol per ton of cane (Brazil average in 2006)

** With the best value of 92 liters of ethanol per ton of cane

*** It is subtracted self consumption of 377 Mcal / t of cane

**** 50% of total mass

Biofuels, Food and Deforestation

Food crop displacement due to biofuel

This problem in Brazil was exhaustively discussed →displacement of food crops in S. Paulo by sugar cane [Homem de Mello, 1980, 1981]

Dimension is different in the case of sugar cane in Brazil and in that of corn in US.

	US corn	Brazil sugar cane
Percentage of World production	54%	33%
Area that is occupied	35 Mha	7 Mha

- The area used to sugar cane production in Brazil is 7 millions ha, about 45% for sugar and 55% for ethanol, that means about 4 millions ha to produce ethanol.
- For comparison, soy bean uses 21 millions ha and cattle pastures occupy 177 millions ha.
- The Country has 152 Mha useful for agriculture.
- Therefore sugar cane for ethanol utilizes only 2.6% of the area for agriculture, without taking into account the recovery of pasture lands that are being degraded.
- 62 Mha are cultivated for producing food, biofuels and other crops.
- So, there are 90 Mha to expand agriculture without deforestation.

The native vegetation area of Brazil is 440 Mha, most of it is in Amazonian rain forest, in the North.

The production of sugar cane is concentrated in the Southeast,

The present impact of sugar cane for ethanol on deforestation is low, in contrast with soybean for exportation and internal market, which includes biodiesel

Production in Brazil per Region

Southeast -	72%	Northeast – 7%	
Center – West –	13%	North -	0.3%
South -	7.7%	Source: Sauer, 2007	

- The situation of soybean, mainly for exportation, but used also for biodiesel, is different → presence in North region is high, although biodiesel production in Brazil is relatively small in comparison with ethanol production.

- Among the goals of Biodiesel Program there were the use of castor oil, palm oil, sun flower and others raw materials produced by small farmers.

- But the present situation is the dominance of soybean large plantations supplying vegetable oil for biodiesel.

- The drivers of deforestation are four, mainly in rain forest:
  - wood extraction;
  - cattle pastures;
  - soybean plantations;
  - mineral resources exploration.

Ethanol - 2006

Production	
USA	18378 millions liters
Brazil	17000
China	3850
India	1900
France	950
Germany	765
Russia	647
Canada	579
Spain	462
South Africa	386

Exportation of Brazil	
EUA	1749 millions liters
Netherlands	344
Japan	228
Sweden	201
El Salvador	183
Jamaica	133
Venezuela	103
TOTAL	3417 millions liters

Source: IEA, 2007

The North-American market is not open to Brazilian ethanol. However, in spite of the weak result of international trade negotiation at multilateral level to open it, there are some reasons to believe in changing the present situation in US:

- Inefficacy of corn ethanol to mitigate global warming
- higher competition of corn ethanol with food agriculture
- lower productivity per hectare and higher cost of corn ethanol
- prediction of expanding the percentage of ethanol to 20% of car fuel

Based in those points, it is reasonable to imagine a scenario for future ethanol demand to be supplied through international trade. The US gasoline consumption is about 10 millions barrels a day. Considering the hypothesis of 20% of ethanol, with 1.3 liter of ethanol for 1 liter of gasoline, the future demand will reach 140 billions liters of ethanol a year, equal to 7 times the present production of Brazil.

- The land area necessary with the same technology and average productivity should be multiplied by seven, resulting 28 Mha for sugar cane, 30.4% of the land that is available to expand agriculture in Brazil.

- This percentage is not small taking into account the need of land for food production and other crops, including biofuels, for internal market and for exportation to other countries besides US.

- Besides, there are the problems of a very large monoculture. Second generation technology for ethanol production must change the present prospects.

The main changes must be at first level:

a) Improvement of efficiency in the transformation of chemical energy of sugar cane bagasse in heat for distillation and in mechanical and electric energy, for self consumption and to sell energy to the grid → present participation of bagasse in the Brazilian electric generation is too small and must increase.

b) Utilization of the sugar cane trash, which is burned before harvesting to allow the manual job of workers; the amount of energy that could be obtained for electric generation is significant.

c) The item (b) implies the increase of harvesting mechanization in sugar cane agriculture, decreasing the number of workers, but job conditions in manual harvesting is hard.

d) The job conditions of workers in sugar cane plantation have to be improved in some cases, including social dimension besides the environmental one in clean energy production.

e) Technological improvement.

In a second level there are:

- gasification of sugar cane bagasse and trash;
- second generation ethanol production through hydrolysis;
- bio-refineries with multiple byproducts
- integrated oil & bio- refineries, in more advanced concept.

Gasification could allow either high efficiency conversion in electric energy through combined cycle or could be used to produce liquid fuel from gas.

Second generation ethanol → hydrolysis (acidic or enzymatic) followed by fermentation that lead to convert fiber (lignin and cellulose) of biomass in ethanol.

The commercial use of hydrolysis can reduce sugar cane comparative advantage in relation to other kind of vegetable to produce ethanol.

For other side the entire mass of sugar cane could be used to obtain ethanol, including the hydrolysis of bagasse and trash, as well as allowing fermentation of pentose to produce ethanol.

- Biodiesel production must be improved in many aspects that are not treated here.

- Biofuels for private cars must not drop the issue of technical and social efficiency in transport system, as the stimulus of public transport.

- Climate Change Policy must be devoted to find realistic solution for sustainable development with social justice.

- Elimination of poverty needs more energy per capita in developing countries, but, at same time, it is necessary to change the intensive energy use and consumption pattern of high income and middle classes.

- It is not possible to mitigate deeply global warming without any change in business as usual energy consumption.