



CO₂ Life Cycle Analysis of Ethanol Production and Use in Brazil



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BRAZILIAN ENERGY MATRIX

➤ Primary Energy Production	%
• Non-Renewable energy	53.9
Oil	43.1
Natural gas	9.0
Coal	1.4
Uranium	0.4
• Renewable energy	46.1
Hydraulic	14.2
Wood	14.4
Products of cane	14.7
Other sources	2.8

Source: BEN 2002

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BRAZILIAN ETHANOL HISTORY

"A SUMMARY"

➤ FROM 1920 – 1928

Different levels of anhydrous ethanol in gasoline

➤ 1928

National plan for sugar, spirits and ethanol

➤ OCT / 1930

Ethanol as an important product for the brazilian sugarcane sector equilibrium

➤ 1931

All gasoline was imported and the importer received the payment if used gasohol (5% ethanol)

➤ 1941

10% ethanol in gasoline

➤ 1945

Quota system for producers (sugar and ethanol)

➤ 1973 and 1980

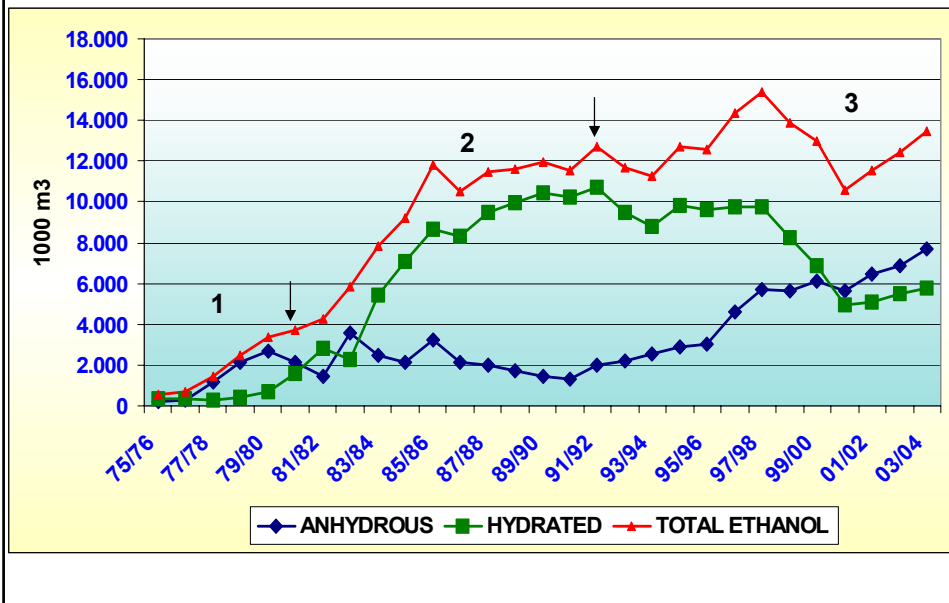
"Oil shocks" and ethanol as the most important product for the sugarcane sector

WORLD ETHANOL PRODUCTION (2000)

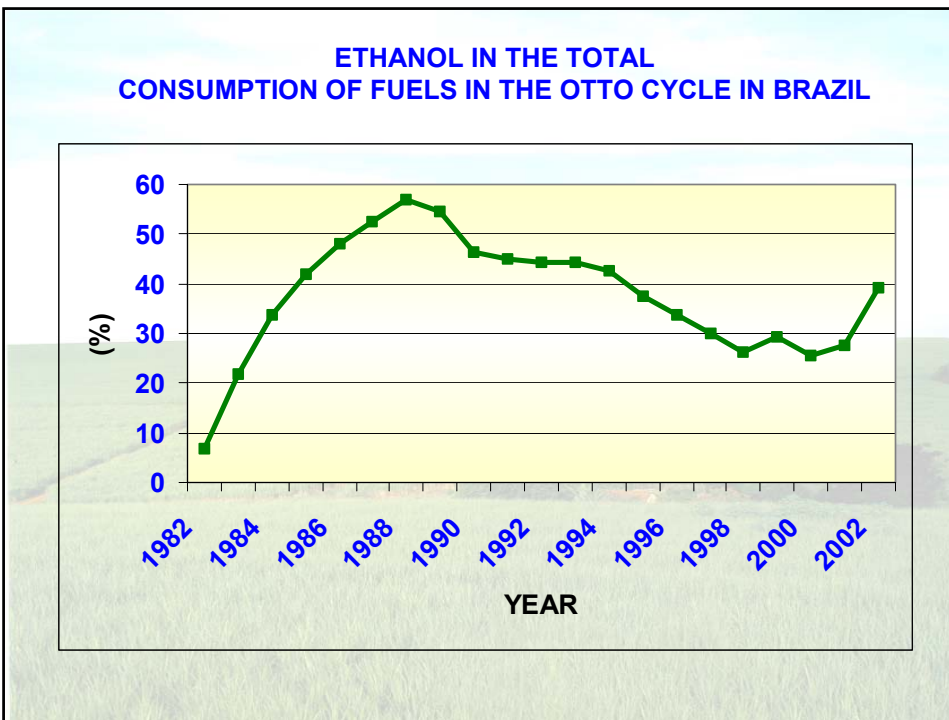
Million M³

Brazil	12.50 (14.4)
USA	6.50 (10.6)
China	3.00
EU	2.00
India	1.70
Russia	1.30
Saudi Arabia	0.40
South Africa	0.38
Others	5.22
TOTAL	33.00

ETHANOL PRODUCTION IN BRAZIL FUNDAMENTAL PHASES



ETHANOL IN THE TOTAL CONSUMPTION OF FUELS IN THE OTTO CYCLE IN BRAZIL



ENERGY BALANCE IN CANE AND ETHANOL PRODUCTION ENERGY LEVELS CONSIDERED

LEVEL 1 – only fuels and electric energy consumed (direct energy input).

LEVEL 2 – add energy consumed in the production of chemicals and other products used (fertilizers, lime, seeds, herbicides, lubricants, sulfuric acid, etc.)

LEVEL 3 – add energy consumed in the production of equipment, buildings and their maintenance.



ENERGY BALANCE IN CANE AND ETHANOL PRODUCTION LIFE CYCLE ANALYSIS: NON – RENEWABLE ENERGY INPUT

	AVERAGE (MJ/TC)	BEST VALUES (MJ/TC)
Sugar Cane Production (total)	201.80	192.00
Agricultural Operations	38.10	38.10
Cane transportation	42.90	36.50
Fertilizers	66.50	63.40
Lime, herbicides, etc.	19.20	19.20
Seeds	5.90	5.60
Equipment	29.20	29.20
Ethanol Production (total)	49.40	39.70
Electricity (bought)	0.00	0.00
Chemicals and Lubricants	6.30	6.30
Buildings	12.00	9.30
Equipment	31.10	24.10



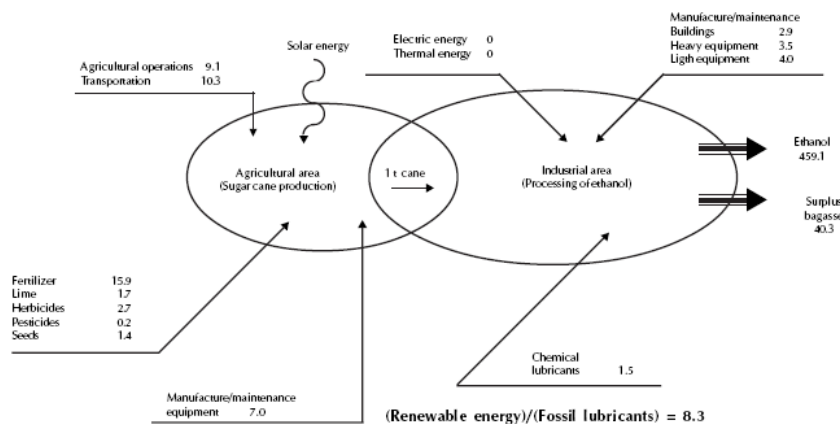
EXTERNAL ENERGY FLOWS (AGRICULTURE + INDUSTRY)

	Input	Output	Input	Output
Agriculture	201.80		192.00	
Industry	49.40		39.70	
Ethanol produced		1921.30		2051.10
Bagasse surplus		168.70		316.40
Total (external flows)	251.20	2090.00	231.70	2367.50
Output/Input		8.3		10.2



ENERGY BALANCE – CONTROL VOLUME

Figure 1 – Energy balance – Scenario 1 (Mcal/TC)



COMPARATIVE ENERGY FLOW IN PRODUCING ETHANOL

PROCESS	Corn ¹	Switchgrass ¹	Sugar cane ²
	(GJ/ha.yr)	(GJ/ha.yr)	(GJ/ha.yr)
Crop production energy comsump.	18.9	17,8	13.9
Biomass Energy	149.5 ³	220.2	297.1 ⁴
Agricultural energy ratio	7.9	12.3	21.3
Ethanol production energy coms.	47.9	10.2	3.4
Energy in ethanol	67.1 ⁵	104.4	132.5 ⁶
Total energy ratio	1.21	4.43	8.32

1- Source: ORNL, 2- Source: Copersucar/UNICAMP, 3-No credit for corn stover, 4- No credit for sugar cane leaves, 5- includes credits for co-products, 6-Includes credits for surplus bagasse 8%

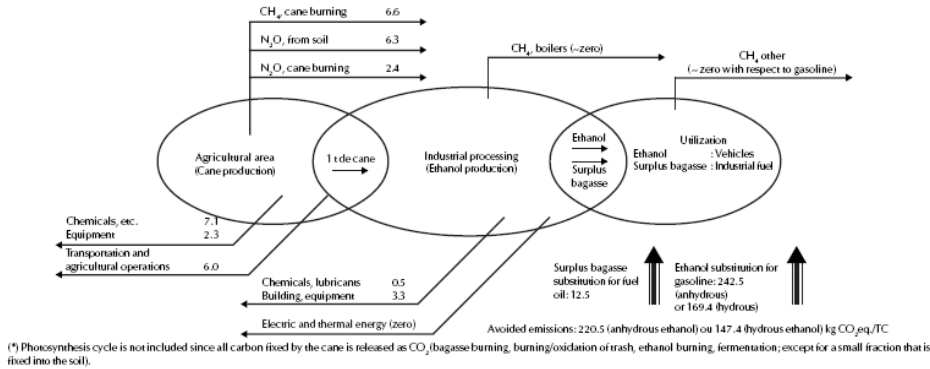
LIFE CYCLE GHG EMISSIONS IN ETHANOL PRODUCTION AND USE

	Kg CO ₂ equiv./t cane			
	Average		Best Values	
EMISSIONS				
• Fossil Fuels	19.2		17.7	
• Methane from cane burning	9.0		9.0	
• N ₂ O from soil	6.3		6.3	
• Total	34.5		33.0	
AVOIDED EMISSIONS (Fossil Fuel Displacement)				
• Use of excess bagasse	12.5		23.3	
• Use of ethanol	242.5(A)	169.4(H)	259.0(A)	180.8(H)
• Total avoided emissions	255.0(A)	181.9(H)	282.3(A)	204.2(H)
NET AVOIDED EMISSIONS				
	220.5(A)	147.4(H)	249.3(A)	171.1(H)
Anhydrous ethanol	2.6 to 2.7 t CO ₂ equiv/m ³ ethanol			
Hydrated ethanol	1.8 to 1.9 t CO ₂ equiv/m ³ ethanol			

Notes: (A) Anhydrous ethanol
(H) Hydrated ethanol

LIFE CYCLE GHG EMISSIONS IN ETHANOL PRODUCTION AND USE Volumes of control

Figure 2 – GHG (*) Emissions – Scenario 1 (kg CO₂eq./TC)



CANE ENERGY

1 TON OF CANE STALKS (CLEAN)

Energy (MJ)

- 140 kg of sugar 2 300
- 140 kg of stalk fiber (bagasse, dry basis) 2 600
- 140 kg of leaves fiber (trash, dry basis) 2 600

TOTAL

7 500 (0.165 TOE)

300 million tons of cane → 50 million TOE/year

Note: Primary energy consumption in Brazil is 235 million TOE/year.

CANE ENERGY ALTERNATIVES

- **SUGAR** → **ETHANOL**
- **FIBER** → **ELECTRIC ENERGY AND/OR ETHANOL**

ELECTRIC POWER GENERATION POTENTIAL

- **BAGASSE ONLY (CRUSHING SEASON ONLY)**

22 bar steam	: 5 kWh/TC
82 bar steam	: 50 kWh/TC

- **BAGASSE + TRASH (YEAR ROUND)**

22 bar steam	: 50 kWh/TC
82 bar steam	: 150 kWh/TC
Gasification	: 250 kWh/TC

CO₂ EMISSION REDUCTION POTENTIAL WITH ELECTRIC POWER GENERATION

- EXISTING TECHNOLOGY: HIGH PRESSURE BOILER / STEAM
TG – 150 kWh/TC
- DISPLACING NG FIRED POWER PLANTS: 500 KG CO₂/MWh
- SUGAR CANE HARVESTING IN BRAZIL: 300 MILLION
TONS/YEAR

AVOIDED CO₂ EMISSIONS : 22 MILLION TCO₂/YEAR



ETHANOL FROM BAGASSE/TRASH

1 t of bagasse or trash (dry basis)

		Ethanol
✓ Cellulose	: 400 kg	200 l
✓ Hemicellulose	: 220 kg	68 l
✓ Lignin	: 200 kg	4 800 MJ
✓ Other	: 180 kg	-

50% BAGASSE + 50% TRASH → 38 L ETHANOL/TC

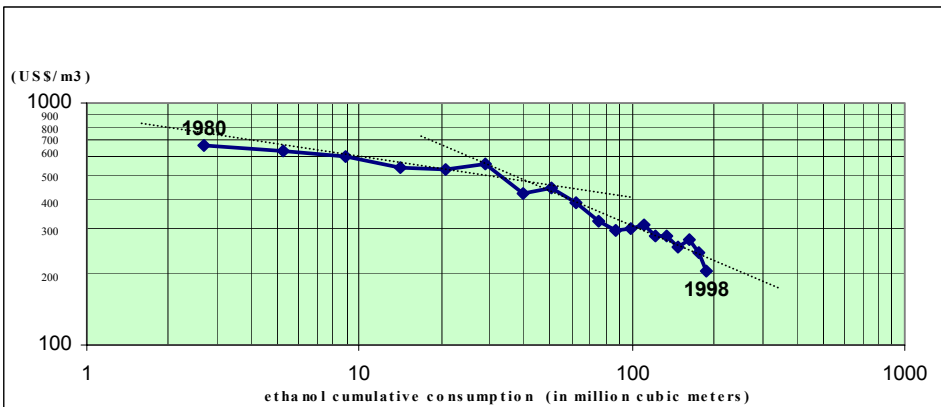


SUSTAINABILITY

- **ECONOMIC** : learning curve
- **ENVIRONMENT** : mitigation measures
- **SOCIAL** : employment



- LEARNING CURVE – BRAZILIAN ETHANOL EXAMPLE AS AN IMPORTANT VIEW FOR BIOFUELS



Source: Goldemberg, J.

ENVIRONMENT MITIGATION MEASURES

- Vinasse and filter cake : recycling
- Water use : 5 m³/TC → < 1 m³/TC
- Cane burning : phase out laws
- Pesticides : replaced by biological control
- Fertilizers : vinasse and filter cake
- Herbicides : trash blanket



Employment

Employment in the production of the vehicle and of fuel
men-year per thousand vehicles

MEN YEAR GENERATED	ALCOHOL VEHICLES	"C" GASOLINE VEHICLES	"A" GASOLINE VEHICLES
Vehicle Production	51.3	51.3	51.3
Fuel Production In 15 years of average life	1,482.0	369.9 ⁽³⁾	18.8
Total Employments	1,533.36	421,2	70,1
Ratio of employments per type of vehicle	21.87 ⁽¹⁾	6.01	1 ⁽²⁾

(1) Considering that an alcohol driven vehicle consumes, on average, 2,600 liters of hydrated alcohol per year, during average work life of 15 years, and that the production of one million liters of alcohol per year, generates 38 direct jobs on average in Brazil.

(2) Considering that a gasoline driven vehicle spends 20% less fuel than a similar alcohol vehicle, and that the production of one million liters of gasoline per year generates 0.6 direct jobs in the country. (Petrobrás had 41,173 employees in 1997, extracting 1 million barrels/day of petroleum and refining 1,45 million)

(3) 24% ethanol and 76% gasoline

Source: UNICA / ANFAVEA / Matriz Energética / Petrobrás