

# 2007 International Fuel Ethanol Workshop



## Process Economics of Ethanol Production in Brazil

An in-depth, independent technical and economic  
evaluation by the **PEP** program

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# Process Economics of Ethanol Production in Brazil

## Agenda

**Brazil's Energy Independence**

**Factors Enabling Biofuels**

**Agricultural Resources**

**Government Support**

**Biofuels Markets**

**Technology Development**

**Capital Issues**

**Conclusions**

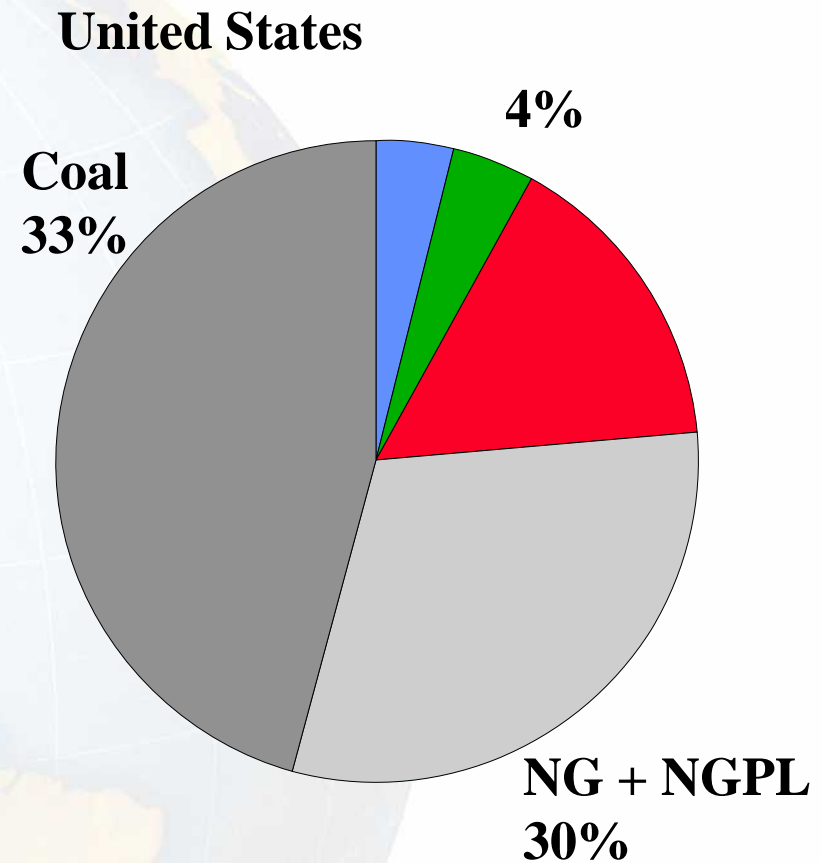
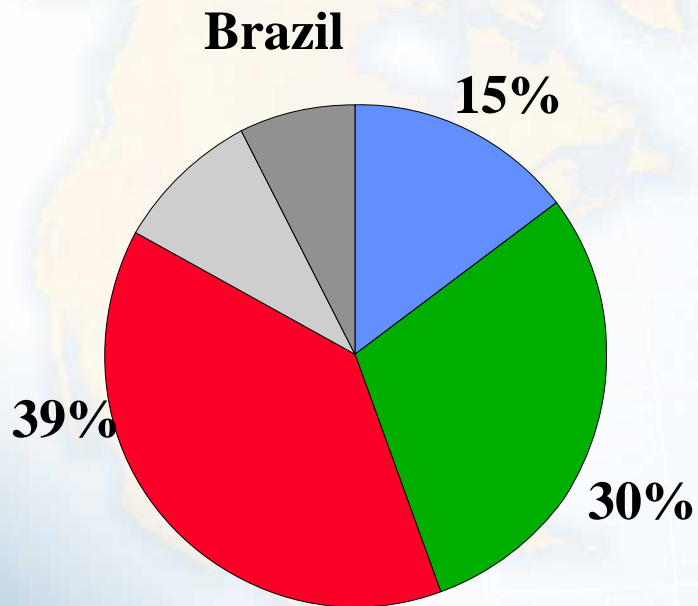
# Why is Brazil unique?

## **Brazil: Case Study in Energy Independence**

- **Increased off shore drilling**
- **Hydroelectric power (77% of total)**
- **Development of biofuels, esp. ethanol**

# Brazil's Renewable Energy Supply

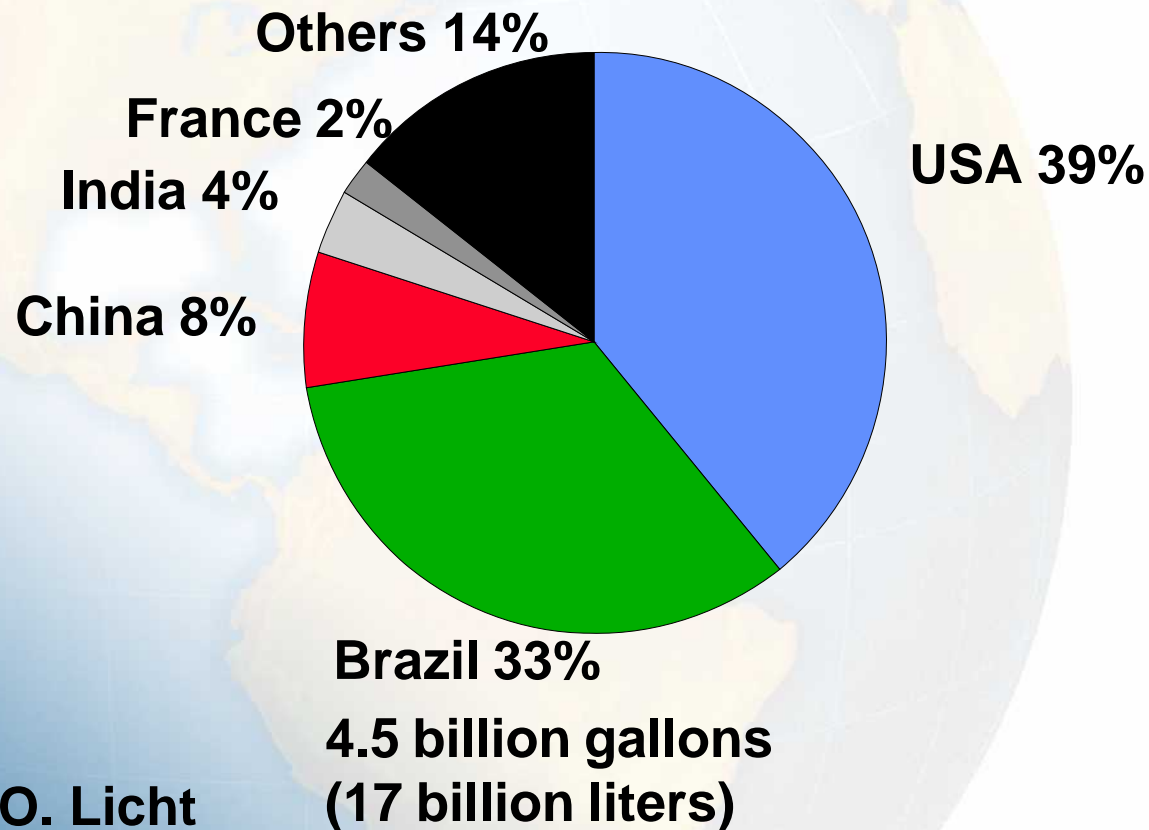
## Combined Electricity/Transportation Energy Supply 2005



Sources: F.O. Licht and Energy Information Administration

# World Ethanol Production

**2006 Production**  
**13.5 Billion Gallons (51 Billion Liters)**



Source: F.O. Licht

# Factors Enabling Biofuels Success

- **Agricultural Resources**
- **Government Support**
- **Biofuels Markets**
- **Technology Development**
- **Investment Capital**

# Agricultural Resources



## United States

**Total 916 million hectares**

**20% cropland (183 mil ha)**

**\*30 million ha corn**

## Brazil

**Total 850 million hectares**

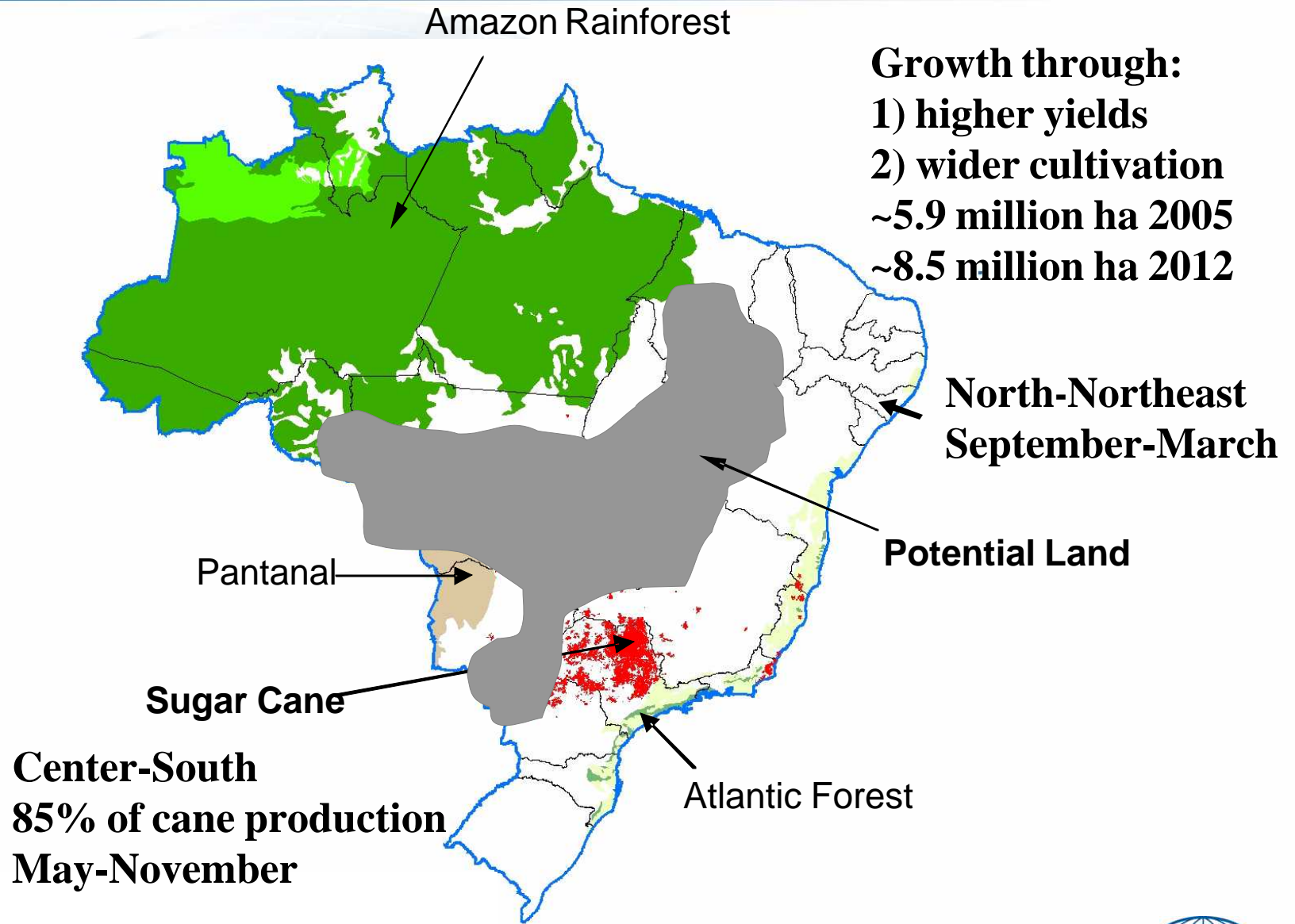
**7% cropland (60 mil ha)**

**\*soy bean – 22 mil. ha**

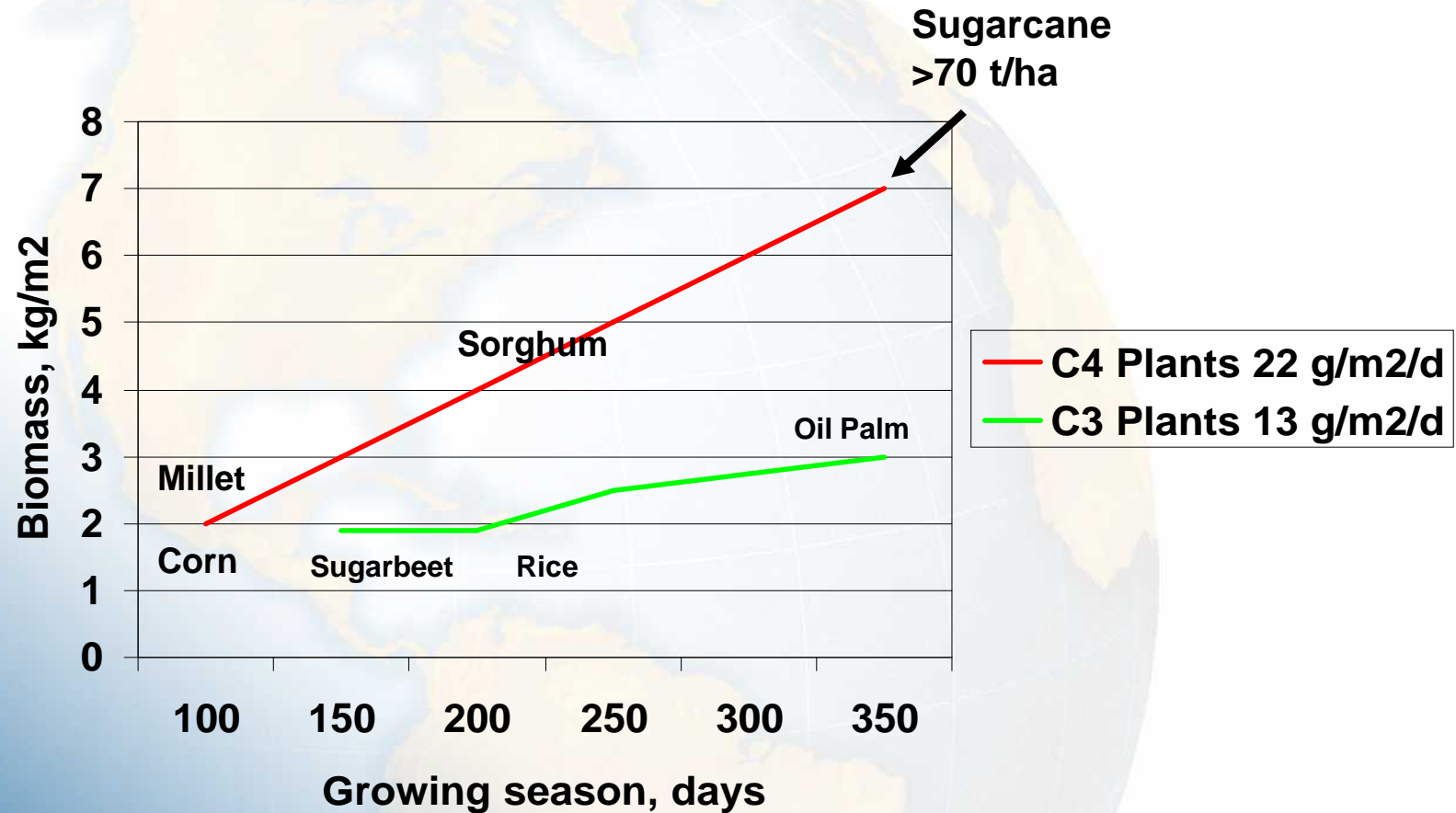
**\*maize – 12 mil. ha**

**\*sugarcane - 5.9 mil. ha**

# Large Area for Potential Growth



# Biomass Growth Rates



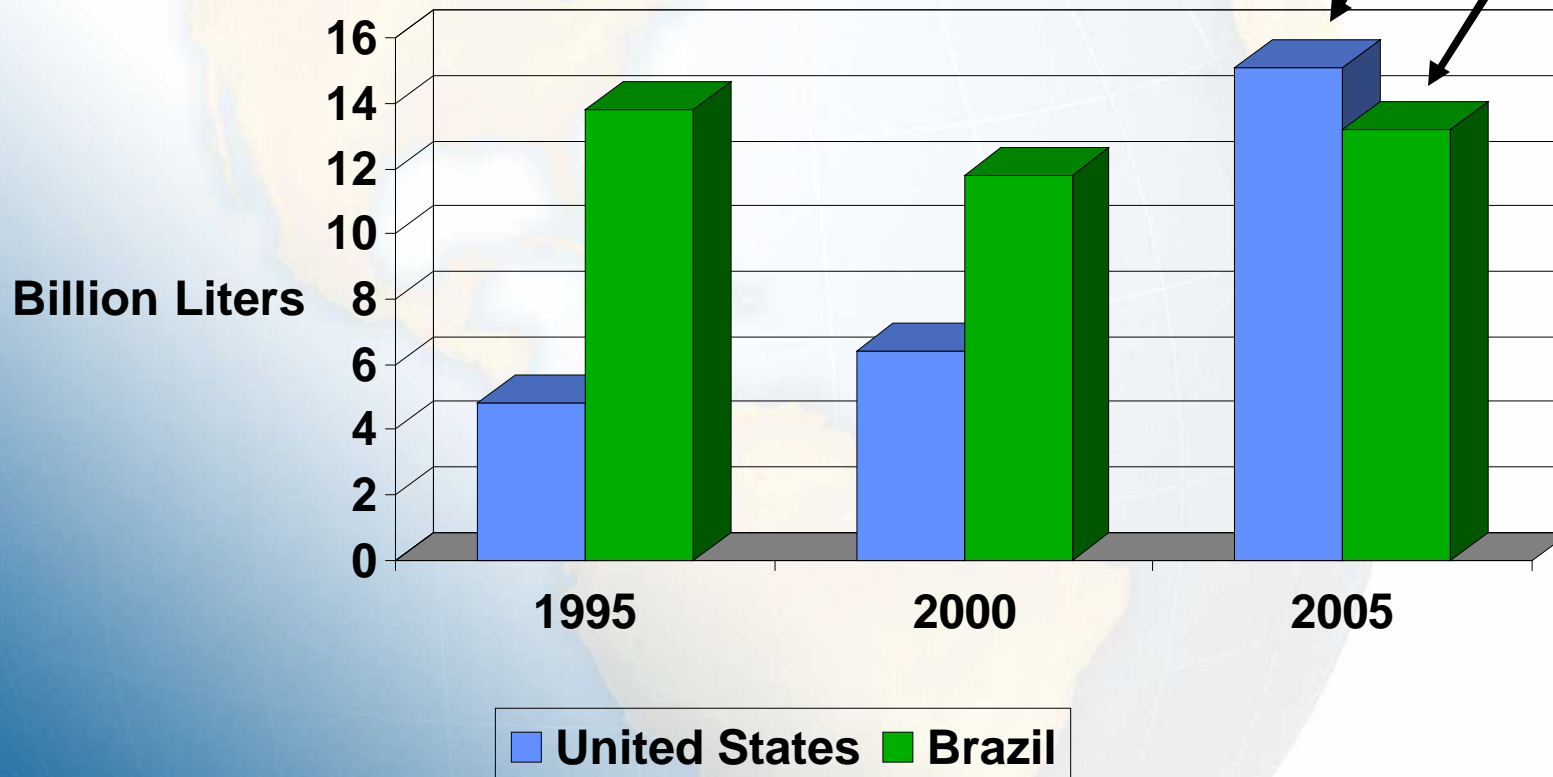
Source: F. Botha, ASSCT Conference 2005

- **National Fuel Alcohol Program (Proalcool) established price supports 1970s**
- **Price supports ended with liberalization of alcohol prices 1999**
- **Ethanol mandate of 20-25% in gasoline**
- **Reduced state and federal fuel taxes**
- **Biodiesel mandate enacted 2005**
  - **2% biodiesel content by 2008**
  - **5% biodiesel content by 2013 (forward to 2010)**
- **U.S./Brazil Biofuels Agreement 2007**
  - **Assist Central America Ethanol Industry**

# Fuel Ethanol Consumption

**Brazilian fuel market highly penetrated  
US market for fuel ethanol still growing**

Passenger  
Vehicle Fuel  
<3% 40%

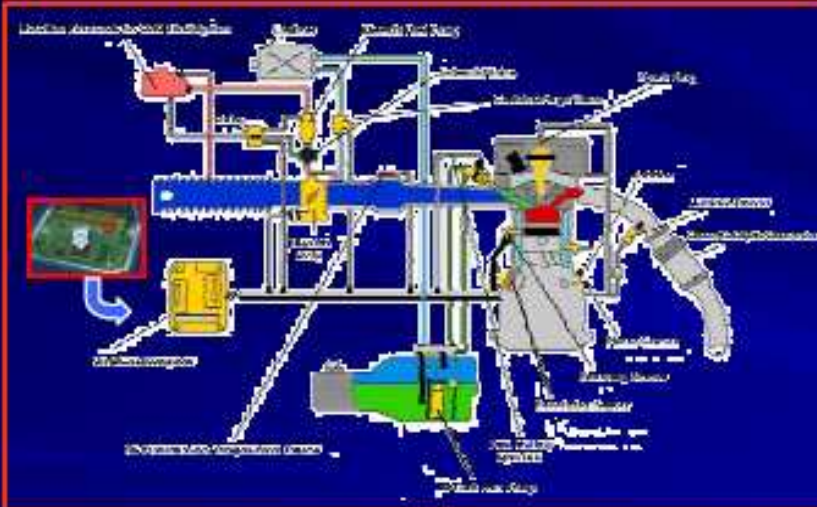


# FFV Dominate Brazilian Auto Sales

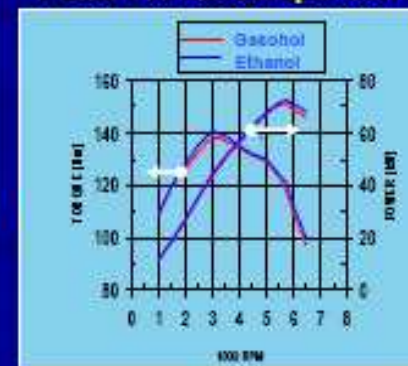


## Flex Fuel Vehicles (FFV)

*Through some special electronic sensors, the on-board computer recognizes the fuel and properly adjust the engine combustion parameters without any interference from the driver.*



### Performance Comparison

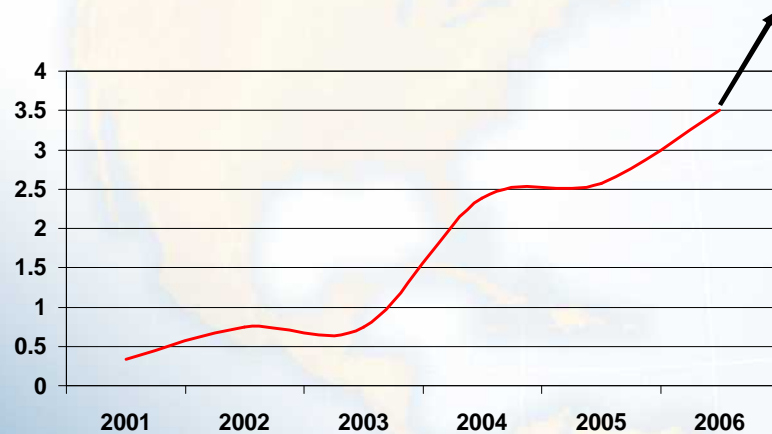


Source: Khosla

## Brazilian Exports

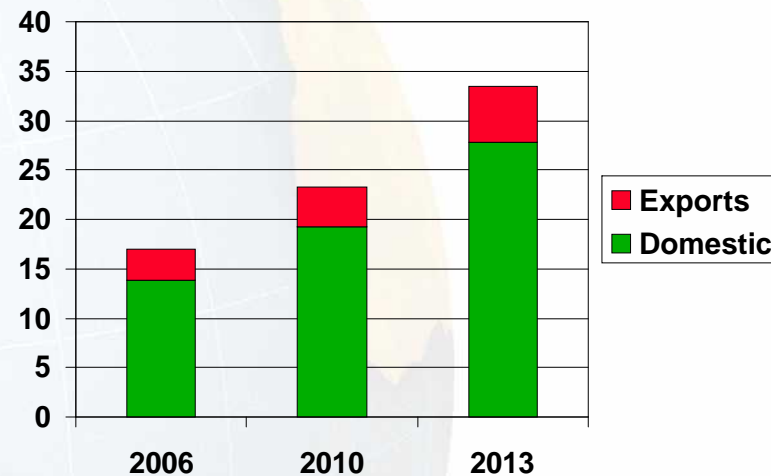
In billion liters

8 billion  
By 2015



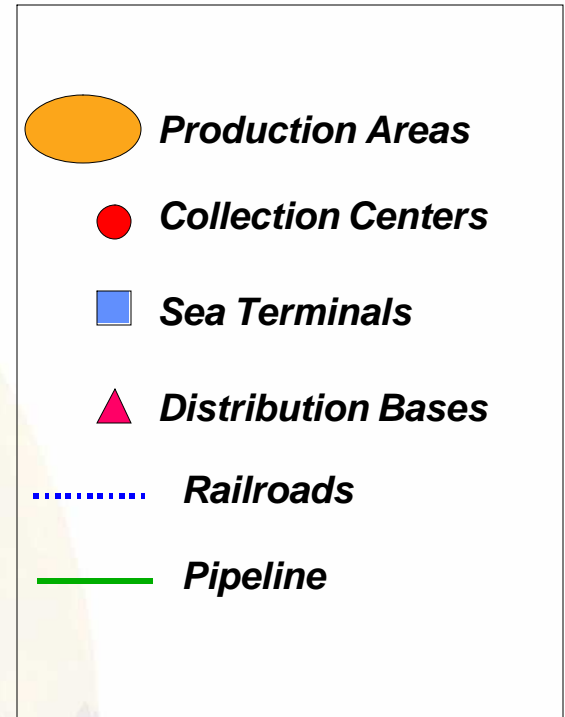
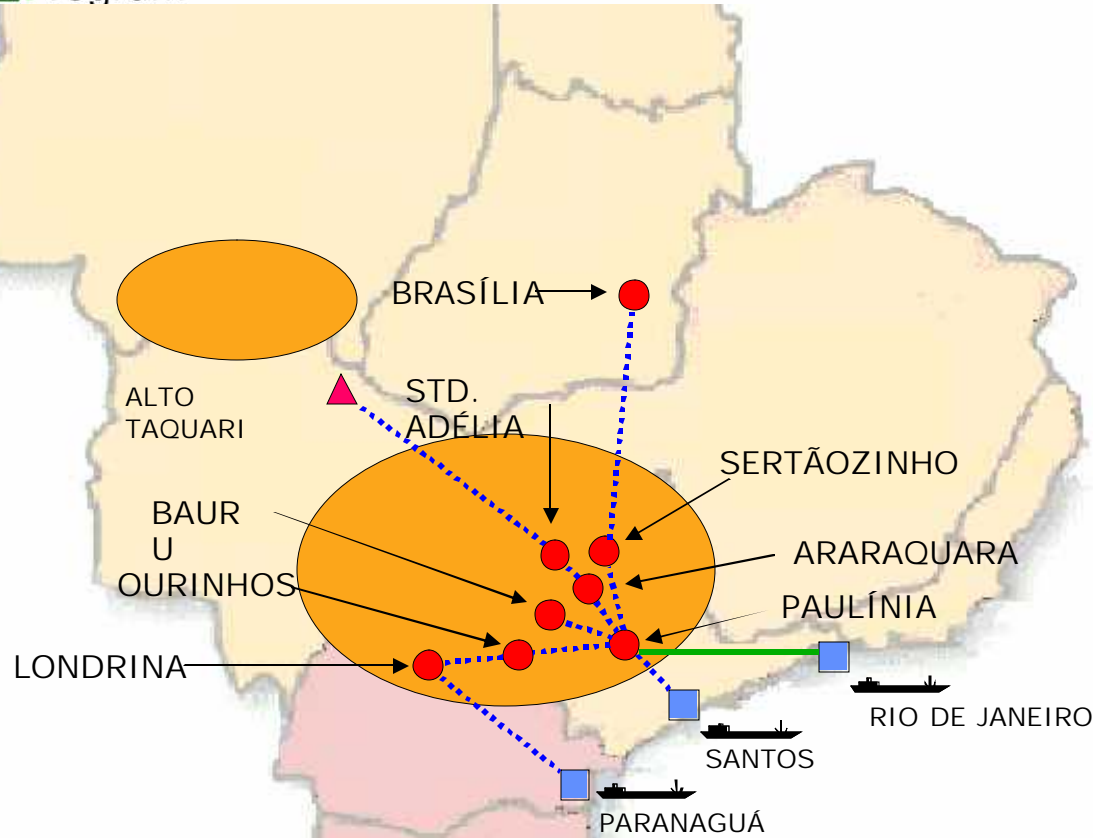
## Production

In billion liters



Source: ATO based on SECEX

# Distribution for Exports



## Export Infrastructure

- a) Petrobras R\$500 mill. Pipeline
- b) Vopak ethanol storage
- c) Harbor investment needed

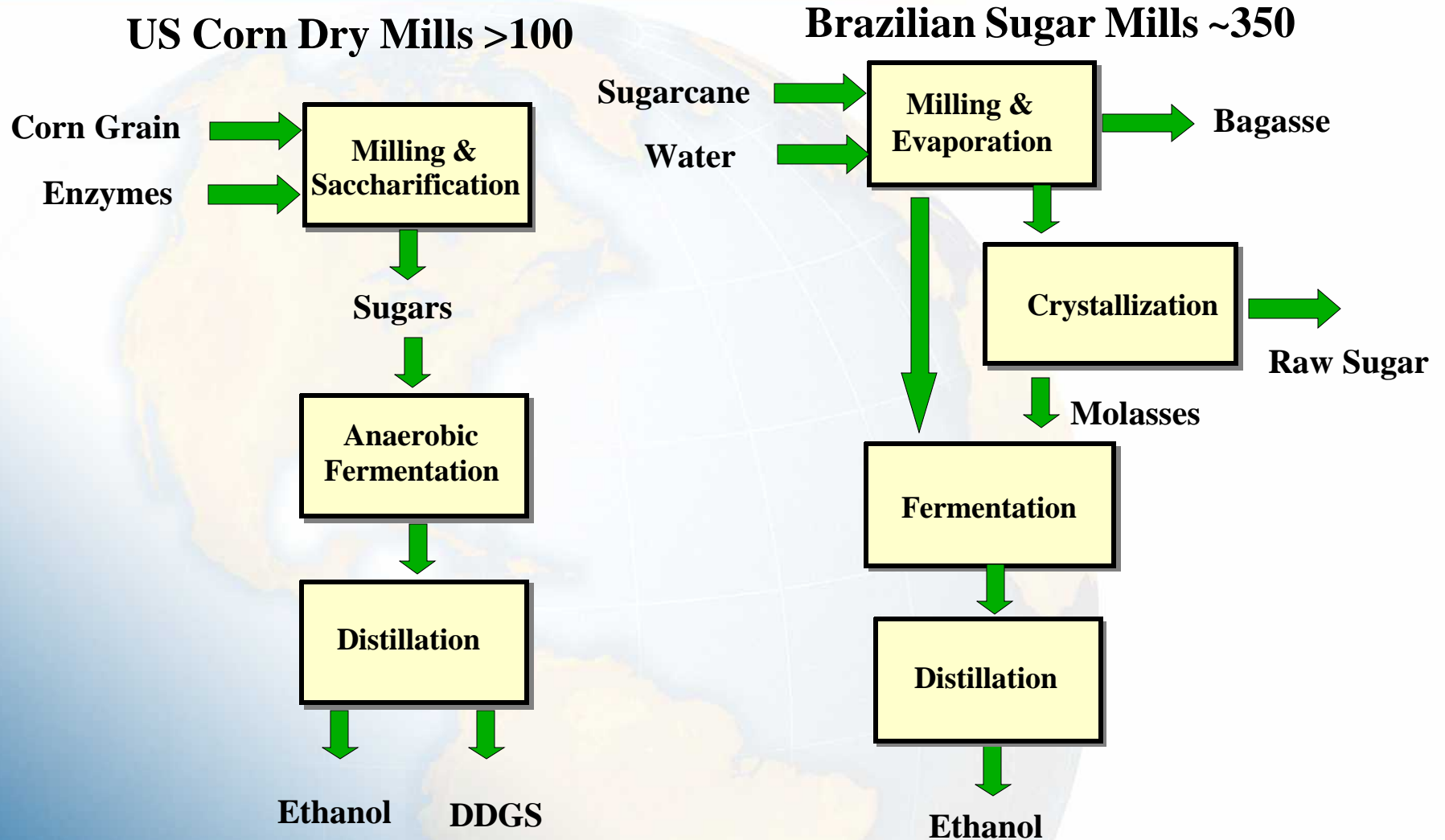
Source: Lepsch 2005

# Ethanol Import Tariffs

	<b>Ad Valorem</b>	<b>Secondary</b>
<b>Brazil</b>	<b>20%</b>	<b>-</b>
<b>Canada</b>	<b>4.92 cents/liter 19 cents/gallon</b>	<b>-</b>
<b>European Union</b>	<b>19.2 cents/liter 87 cents/gallon</b>	<b>-</b>
<b>India</b>	<b>186%</b>	<b>-</b>
<b>United States*</b>	<b>2.5%</b>	<b>14 cents/liter 54 cents/gallon</b>

**\*Significant exemption under Caribbean Basin Economic Recovery Act**

# Competing Ethanol Producers



**Both concepts can be advanced:  
economies of scale and process technology**

# World Class Equipment Manufacturers

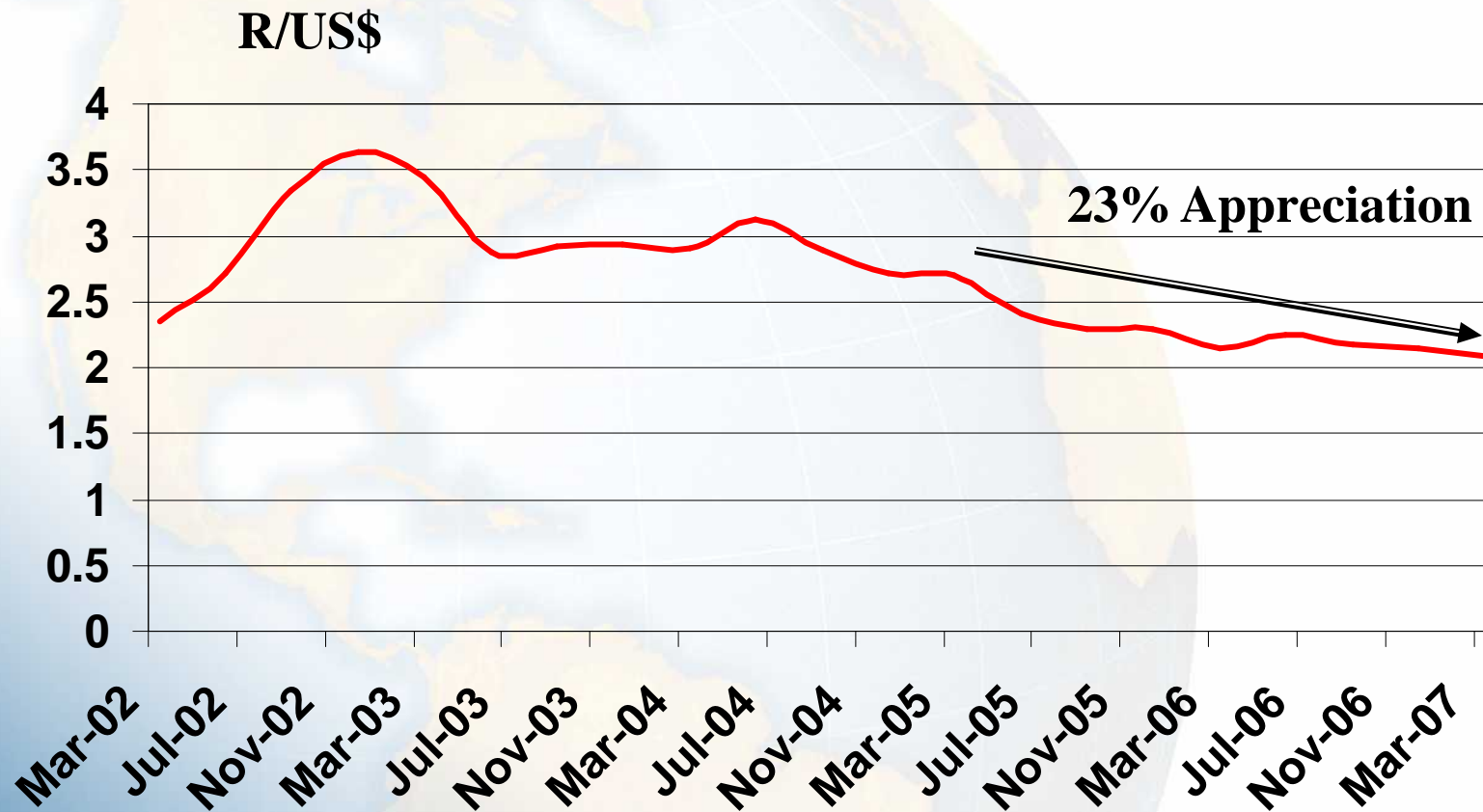


**DEDINI MCD-01 - 1º TERNO DE MOENDA 56"x100" (1.422 x 2.540 mm)**

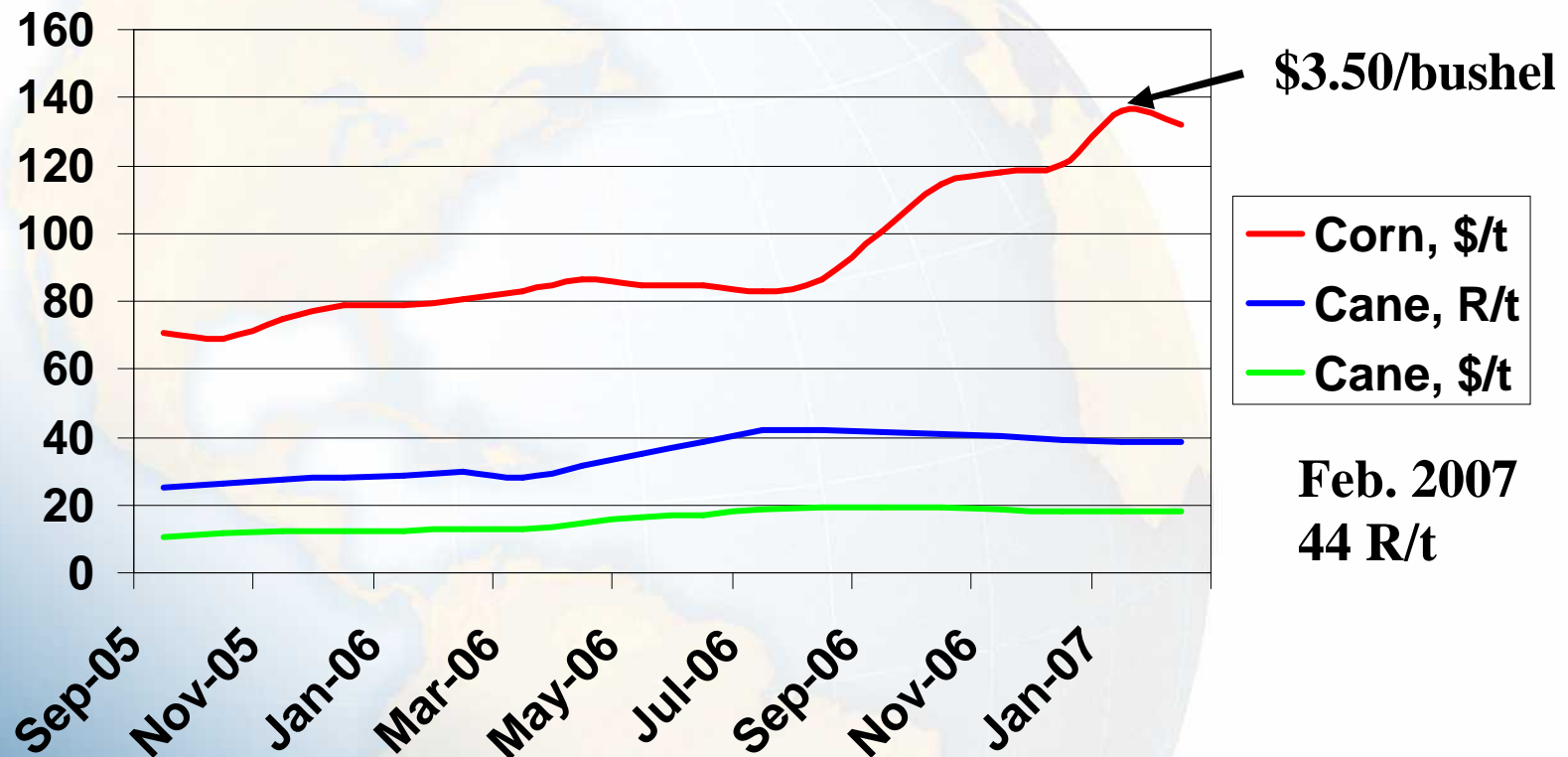
**28,000 Tons Cane/Day**

**Source: Oliverio**

## Brazilian Real Continues to Appreciate



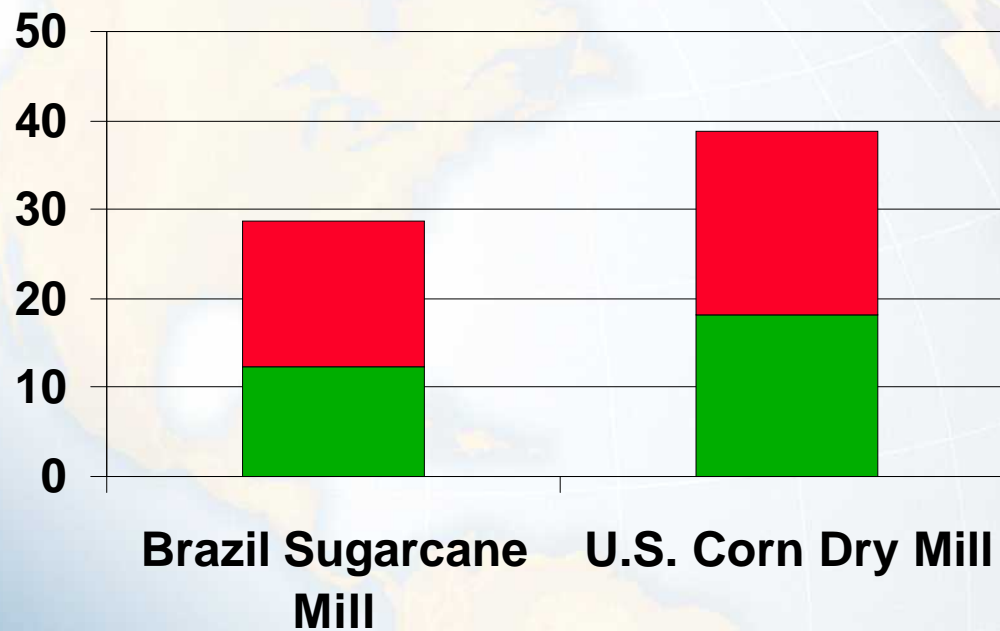
**Appreciation rates, Sept 2005-Feb 2007**  
**Corn = 86%, Cane(R) = 52%, Cane(\$)** = 67%



Sources: USDA and F.O. Licht

# Relative Ethanol Production Costs

## Mid-2006 Net Production Cost US cents/liter



**Corn = \$2.5/bushel**  
**Cane = 42 R/tonne**

**Net raw materials**  
**Other\***

**\*Includes:**  
Utilities  
Waste treatment  
Labor  
Maintenance  
Plant overhead  
Depreciation  
GASR

**Million liters/yr: 164**

**190**

**Source: SRIC Process Economics Program**

## Interesting areas of development:

- **GM Sugarcane, e.g. Fiber Cane**
- **Lignocellulosic Conversion**
- **Ethanol/Biodiesel Integration**
- **Ethanol as Chemical Feedstock**

# Sugarcane GM Technology

- **Worldwide research underway**
- **Brazil field trials in progress**
- **Many traits under investigation:**
  - **Herbicide resistance**
  - **Insect resistance**
  - **Disease resistance**
  - **Sucrose levels**
  - **Polymers**
  - **Increased cellulose (energy cane) by Alellyx**

# Fiber Cane Potential

**ANOTHER TWO FOLD INCREASE IN PRODUCTIVITY COULD BE OBTAINED WITH THE USE OF SUGAR CANE VARIETIES SELECTED TO PRODUCE BIOMASS INSTEAD OF SUCROSE**

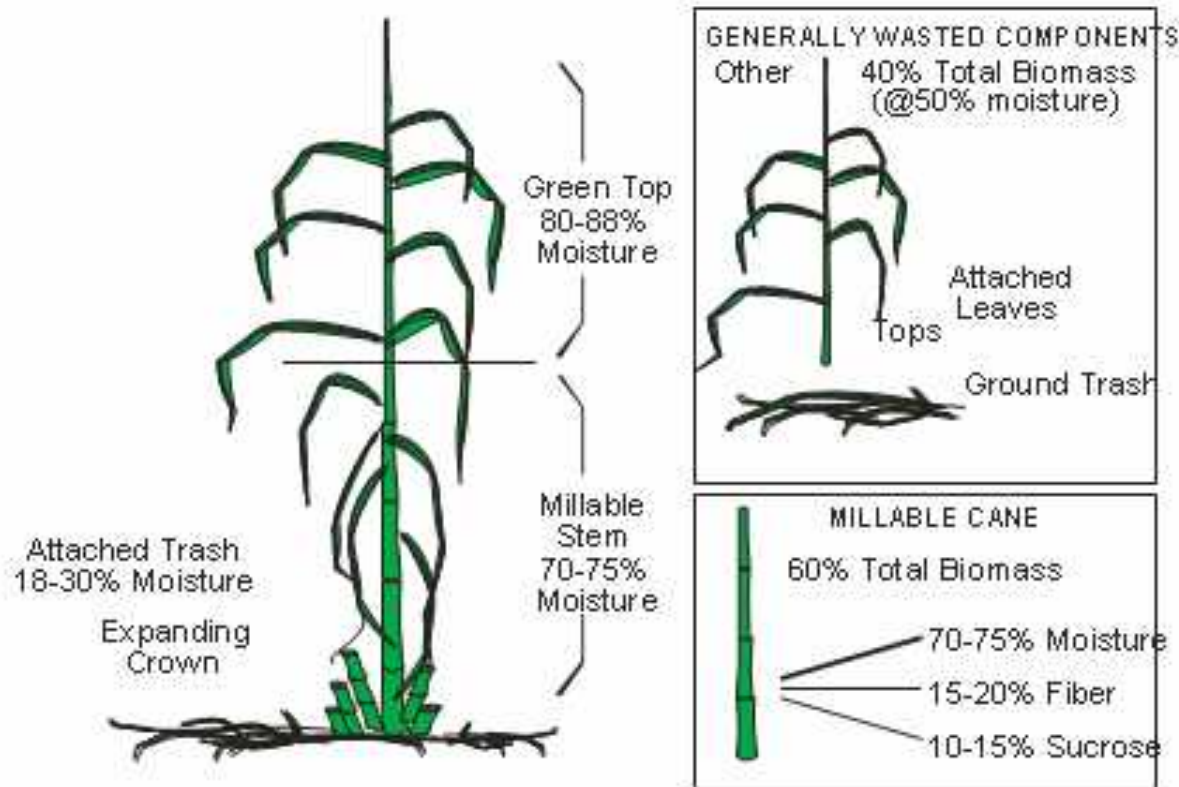
<b>Cane productivity</b>	<b>Ton/ha (wet weight)</b>	<b>Ton/ha (dry weight)</b>
Conventional cane	70 - 120	21 - 36
Fiber cane	140 - 240	49 - 84

**(Liters of ethanol/ha)**

<b>Biomass source</b>	<b>Sugar</b>	<b>Cellulose</b>	<b>Hemi cellulose</b>	<b>Total</b>
Conventional cane	6,400	5,652	2,013	15,105
Fiber cane	11,508	14,457	4,243	30,208

**Source: Reinach 2006**

## Development of whole crop utilization in Brazil



**Residue:**

- left in field
- potential as fuel or feedstock

**Bagasse:**

- burned as fuel
- feedstock potential

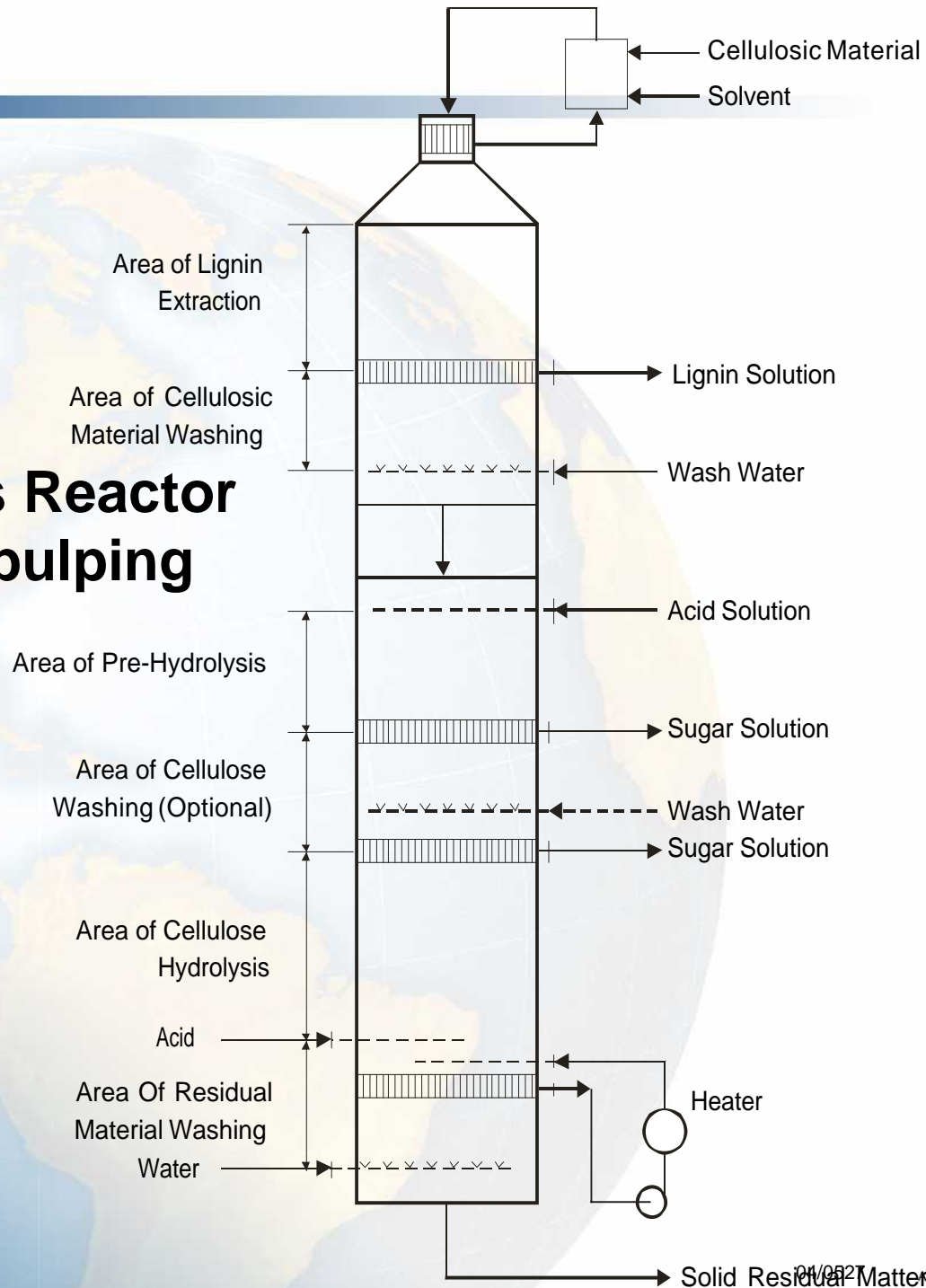
# BRAZILIAN SUGARCANE BAGASSE

## 122 Million Tons in 2005



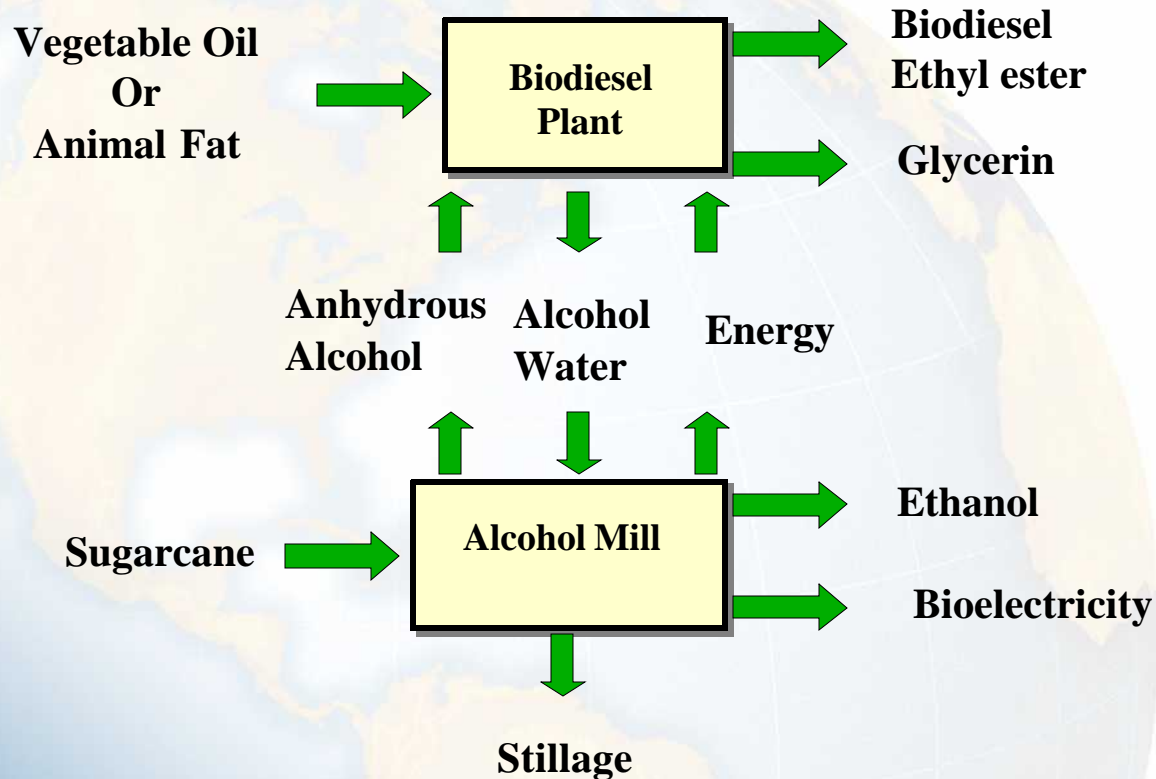
- **Bagasse Pretreatment**
  - **Dedini organosolv process**
    - ◆ **Ethanol/water solvent**
    - ◆ **Sulfuric acid hydrolysis**
    - ◆ **2004 pilot unit**
    - ◆ **Bagasse feed problems**
  - **Oxiteno hydrolysis reactor**
    - ◆ **Submitted plans to BNDES in 2006**
    - ◆ **Specialized pulp type reactor**

**Oxiteno Hydrolysis Reactor**  
**-Resembles wood pulping**  
**-Demo unit 2006**  
**-WO 2006/086861**



# Ethanol/Biodiesel Integration

## Lower biodiesel costs through integration



**Barralcool Mill in Barra do Bugres**  
**-Based on Dedini technology**  
**-2006 startup**

Source: Oliverio 2005

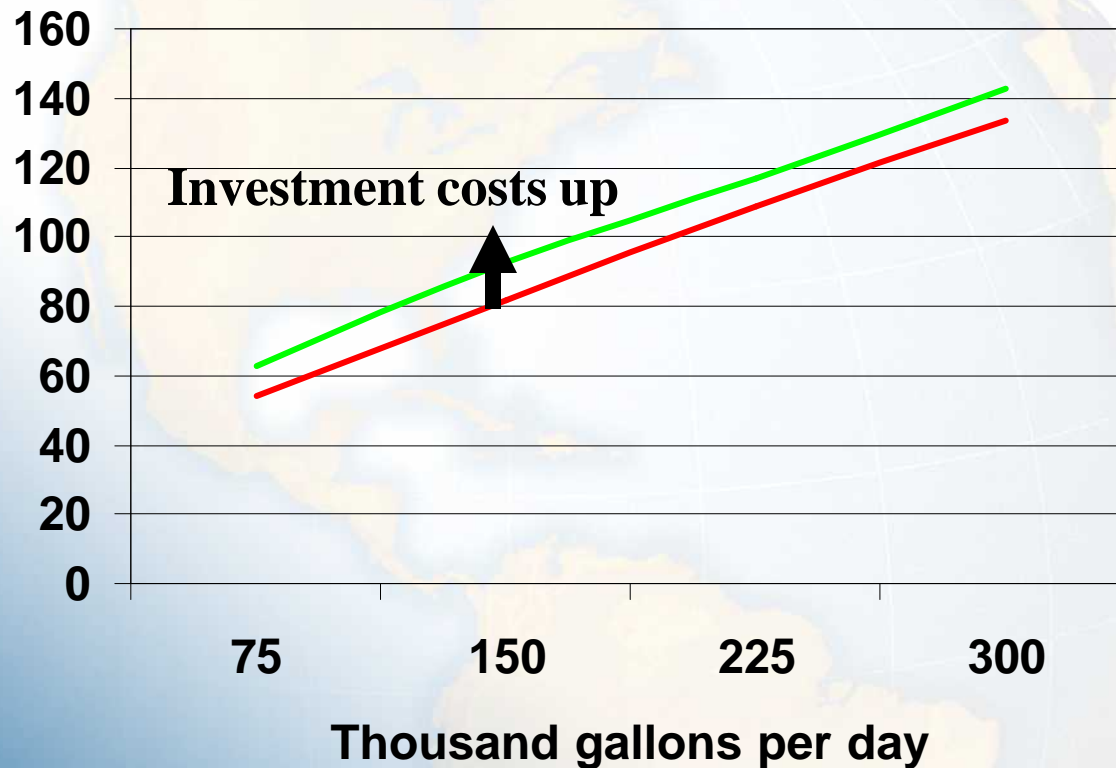
# Ethanol as Chemical Feedstock

- **Ethylene from ethanol**
  - **Koppers, Petrobras, Scientific Design, and Union Carbide fixed bed technology in practice through early 1990s**
  - **Braskem and Petrobras developing improved fixed bed technology**
- **Acetic acid from ethanol**
  - **Rhodia**
- **Ethyl acetate directly from ethanol**
- **ETBE**
  - **Braskem shifting from MTBE**

# Total Fixed Capital Investment

**Ethanol production is capital intensive.**

Million US\$ in mid-2006



— Corn Dry Mill  
— Sugarcane Mill

**Sugarcane Mill:**  
-2.2 Reais/US\$  
-No capital for sugar crystallization

Source: PEP Report 149A

- **Brazilian Development Bank (BNDES)**
  - Historically funded sugarcane mills
  - Grown from \$R580 mil 2004 to \$R2 bil 2006
- **High interest rates of 15-25% in Brazil**
- **With high sugar prices, some self-funded mills**
- **Seeking foreign investment for future expansions**  
**86 new plants over next 5 years**
  - French companies, Tereos and Louis Dreyfus
  - American venture capitalists, Carlyle Group and Riverstone Holdings, Khosla
  - Brazilian Renewable Energy Co. (Brenco)

## Brazil is well positioned for biofuels

- Large and growing agriculture industry
  - Sugarcane highly efficient crop
- Ethanol market established and biodiesel growing
- Available capital growing
- Technology development underway
  - GM fiber cane and bagasse processing
  - Ethanol/biodiesel integration
- Very dynamic competitive situation in biofuels

- **Bohlmann and Cesar, PEP Report 149A, Ethanol Production in Brazil (Oct. 2006)**
- **Bohlmann, “Biorefinery Process Economics,” *Chemical Engineering Progress*, (Oct. 2005)**
- **Bohlmann and Cesar, “The Brazilian Opportunity for Biorefineries,” *Industrial Biotechnology*, (Summer 2006)**

**Thank you for your attention**

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