1st Brazilian BioEnergy Science and Technology Conference

Campos do Jordão

“An historical account of bioenergy production in Brazil”

Prof. José Goldemberg

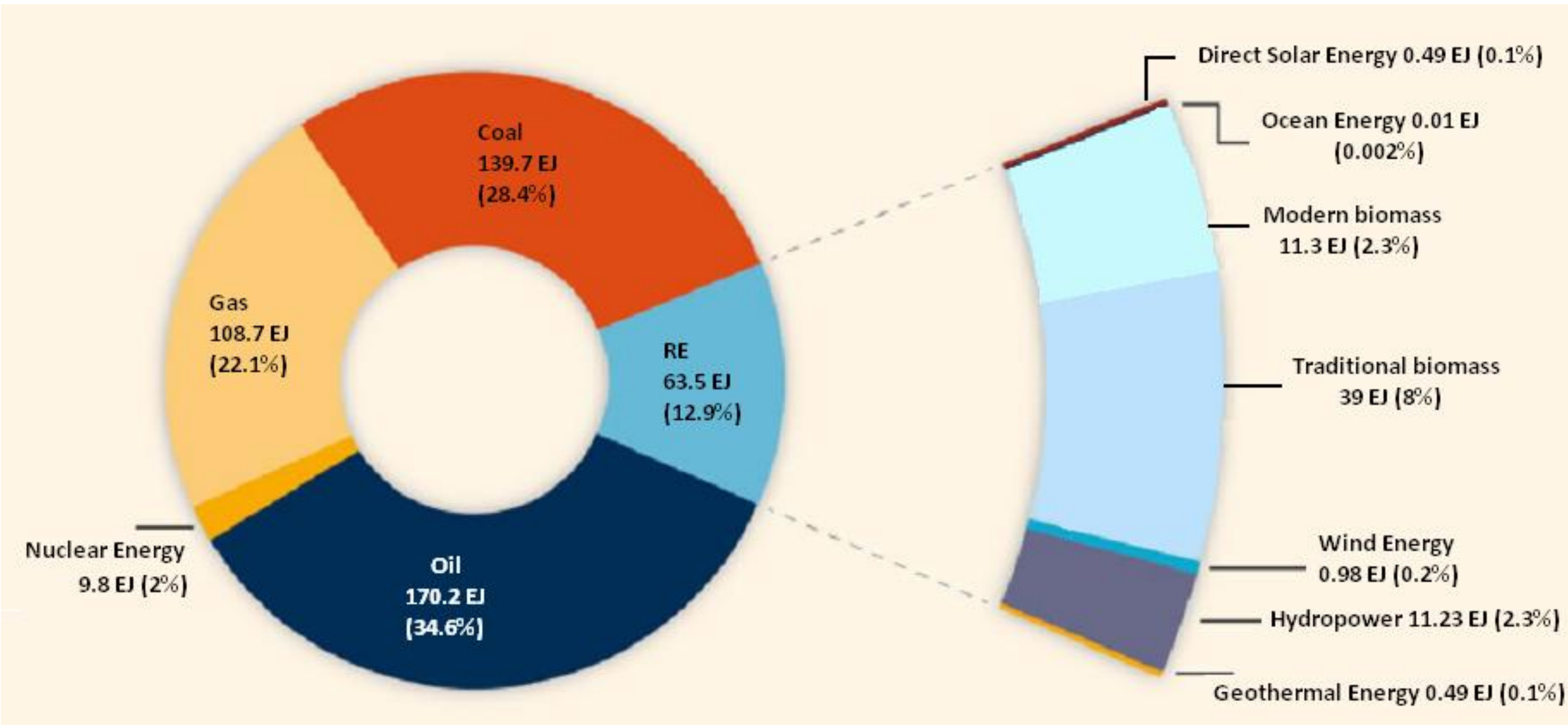
August 14 2011

An historical account of bioenergy production in Brazil

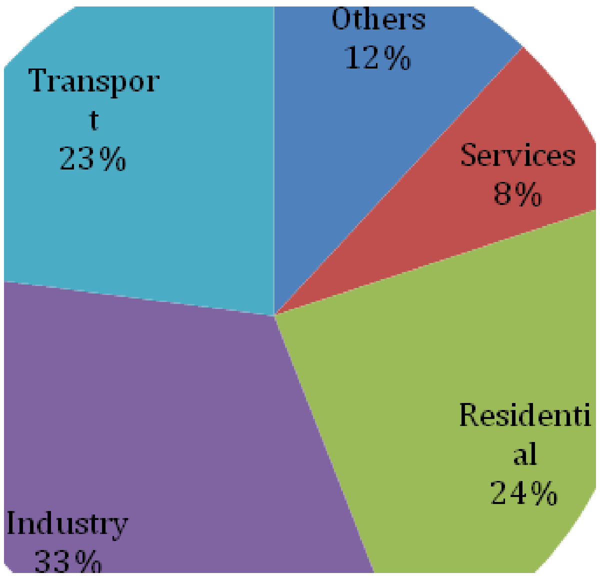
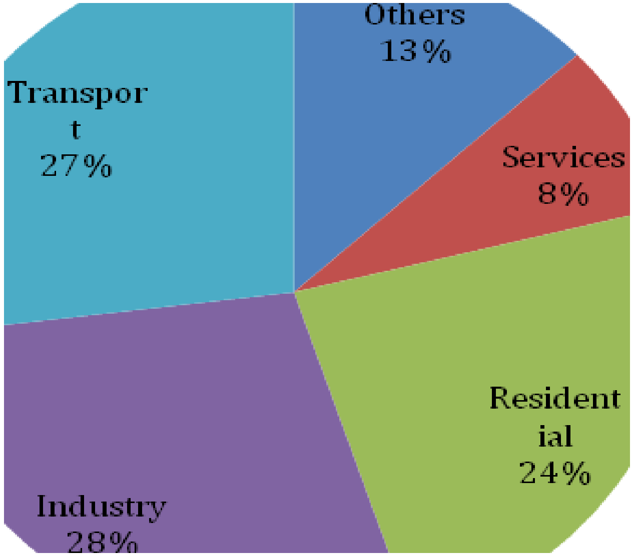
Outline

1. The challenge of transportation
2. The ethanol program in Brazil
3. The expansion of the program
4. Sustainability concerns

WORLD'S PRIMARY ENERGY SUPPLY 2008

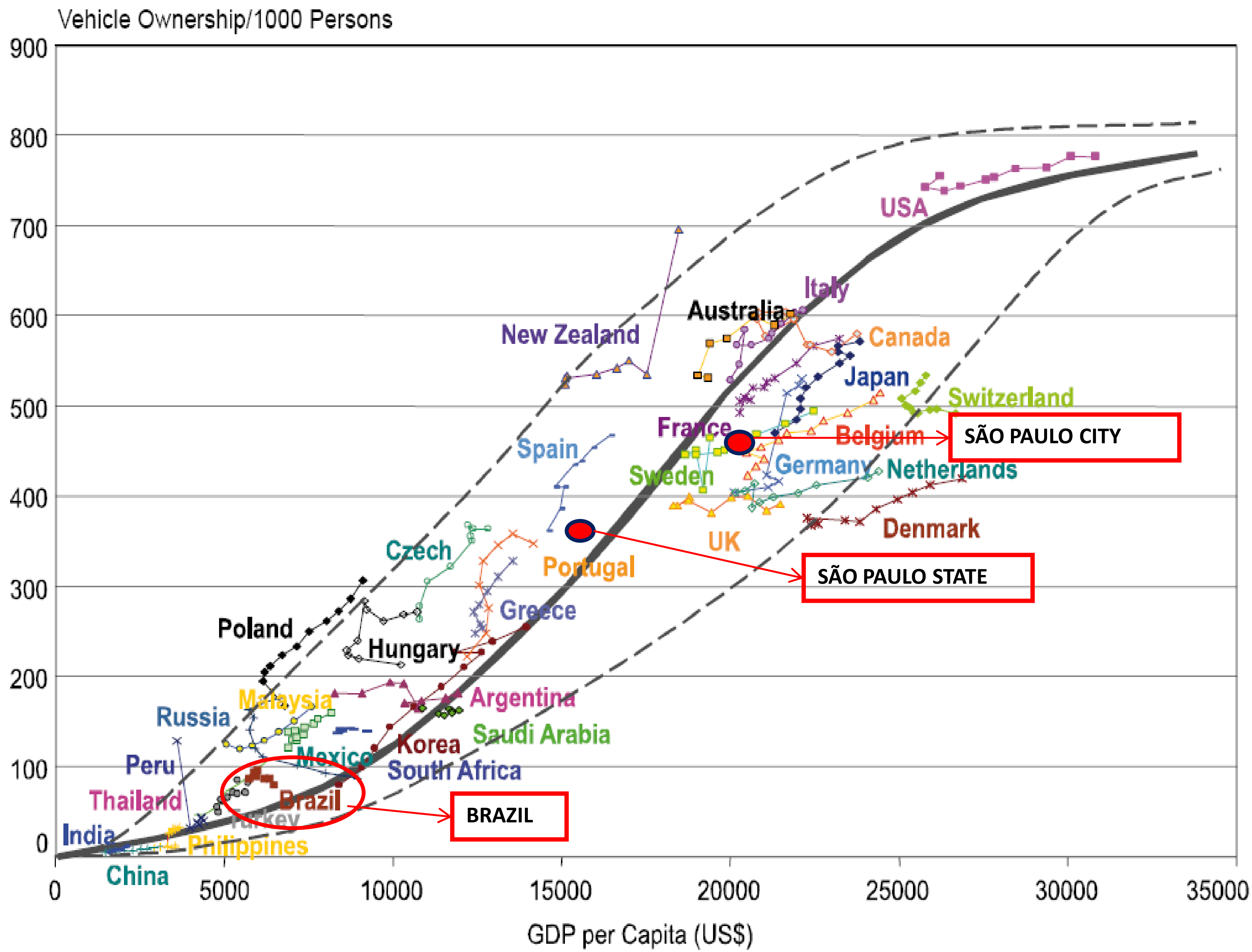


WORLD ENERGY CONSUMPTION

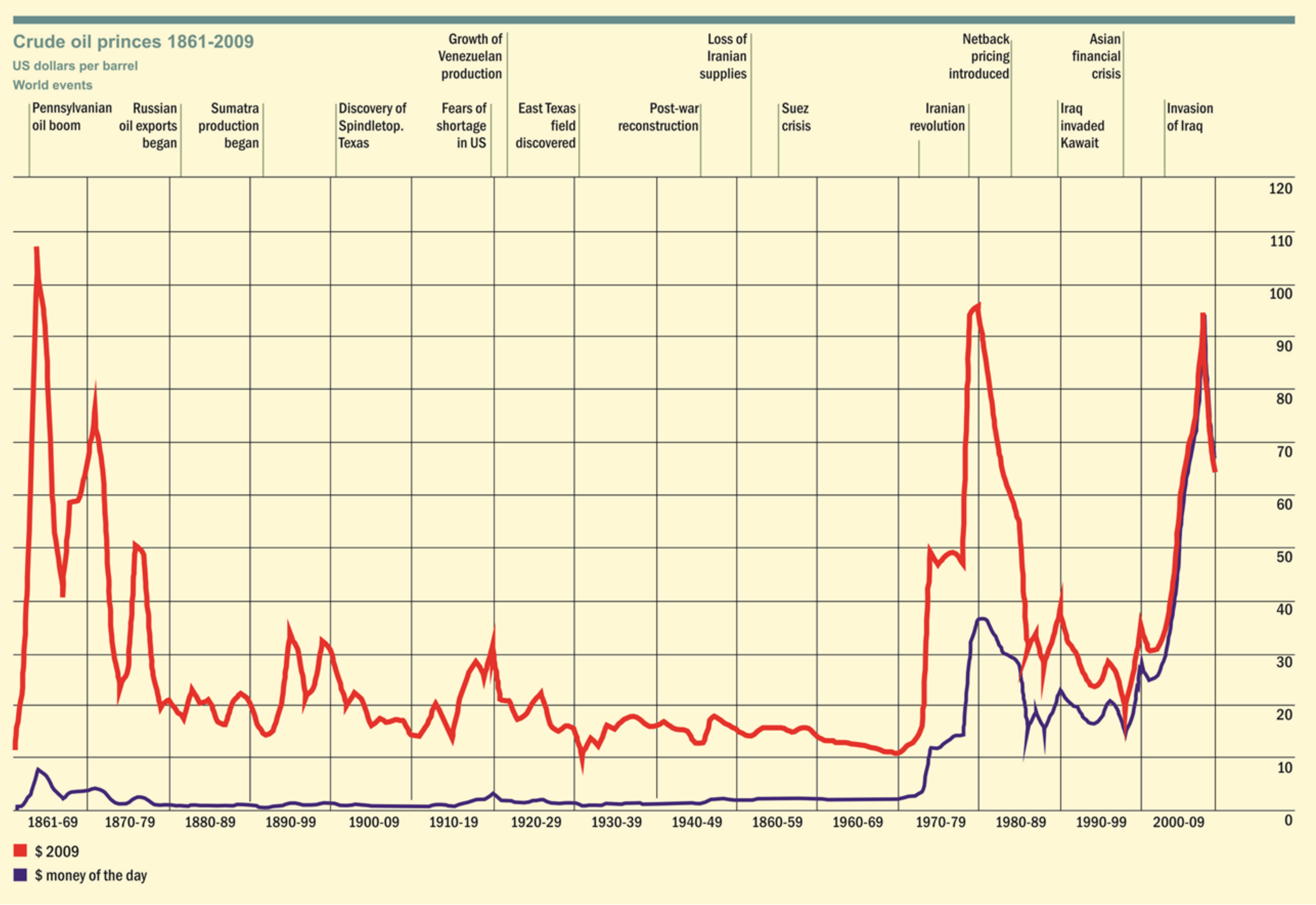
1971	2008
	

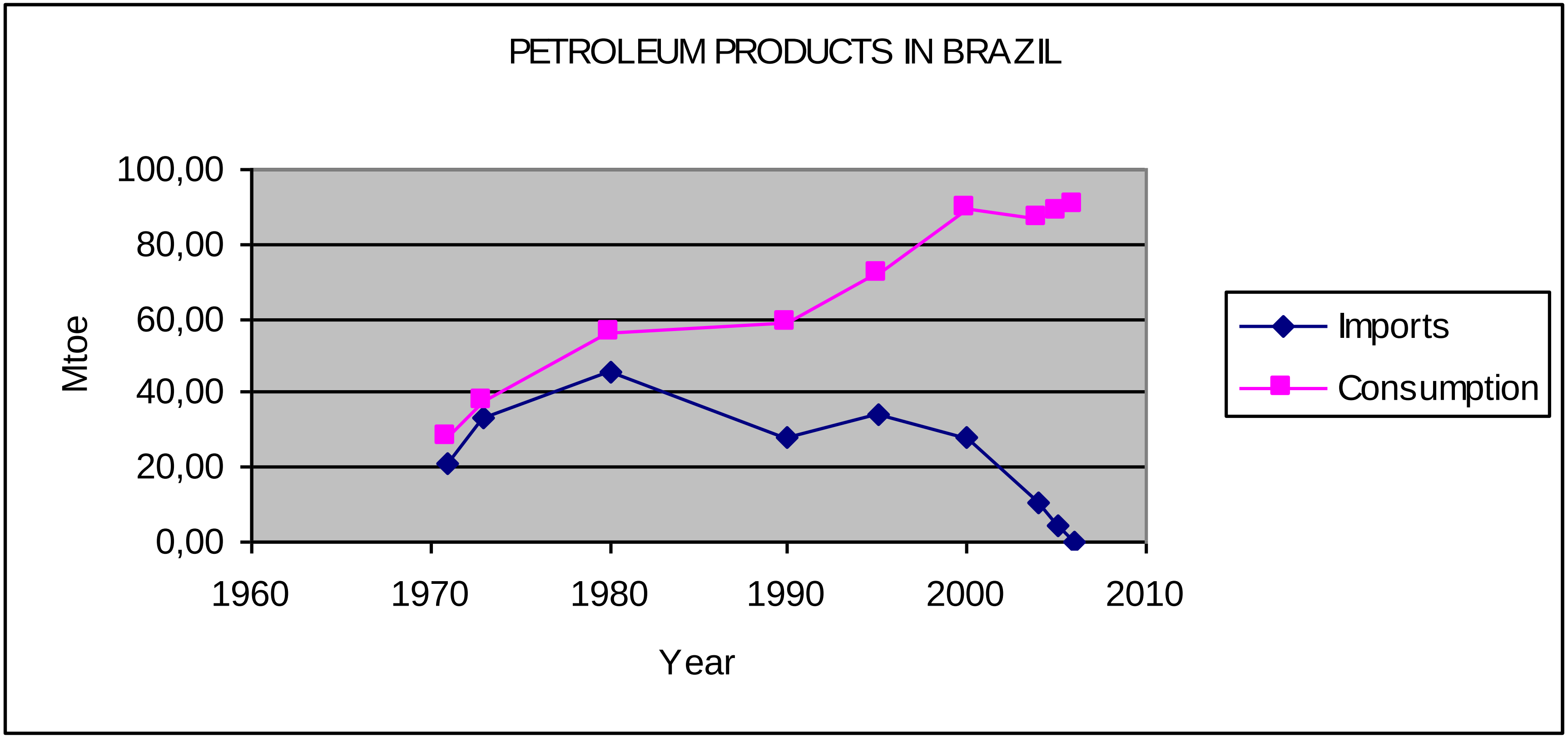
Transportation shares in final energy consumption (%)

	1971	2008
OECD	24	33
Non-OECD	13	18
World	23	27



Vehicle Ownership/1000 Persons
900
800
700
600
500
400
300
200
100
0
0
5000
10000
15000
20000
25000
30000
35000
GDP per Capita (US$)
USA
Italy
Australia
Canada
New Zealand
Japan
Switzerland
France
Belgium
SÃO PAULO CITY
Spain
Germany
Netherlands
Sweden
UK
Denmark
Czech
Portugal
SÃO PAULO STATE
Greece
Poland
Hungary
Malaysia
Argentina
Russia
Saudi Arabia
Korea
Mexico
Peru
South Africa
Thailand
Brazil
BRAZIL
Turkey
India
Philippines
China


Crude oil princes 1861-2009
US dollars per barrel
World events
Pennsylvanian oil boom
Russian oil exports began
Sumatra production began
Discovery of Spindletop. Texas
Fears of shortage in US
Growth of Venezuelan production
East Texas field discovered
Post-war reconstruction
Loss of Iranian supplies
Suez crisis
Iranian revolution
Netback pricing introduced
Iraq invaded Kawait
Asian financial crisis
Invasion of Iraq
120
110
100
90
80
70
60
50
40
30
20
10
0
1861-69
1870-79
1880-89
1890-99
1900-09
1910-19
1920-29
1930-39
1940-49
1860-59
1960-69
1970-79
1980-89
1990-99
2000-09
$ 2009
$ money of the day


PETROLEUM PRODUCTS IN BRAZIL
100,00
80,00
60,00
40,00
20,00
0,00
Mtoe
1960
1970
1980
1990
2000
2010
Year
Imports
Consumption

"Birth certificate" of the Ethanol Program in Brazil

I. The expansion of ethanol production

Decree 76593 (November 14,1975)
The price of ethanol should be at parity with sugar and 35% higher than the price of 1kg of sugar

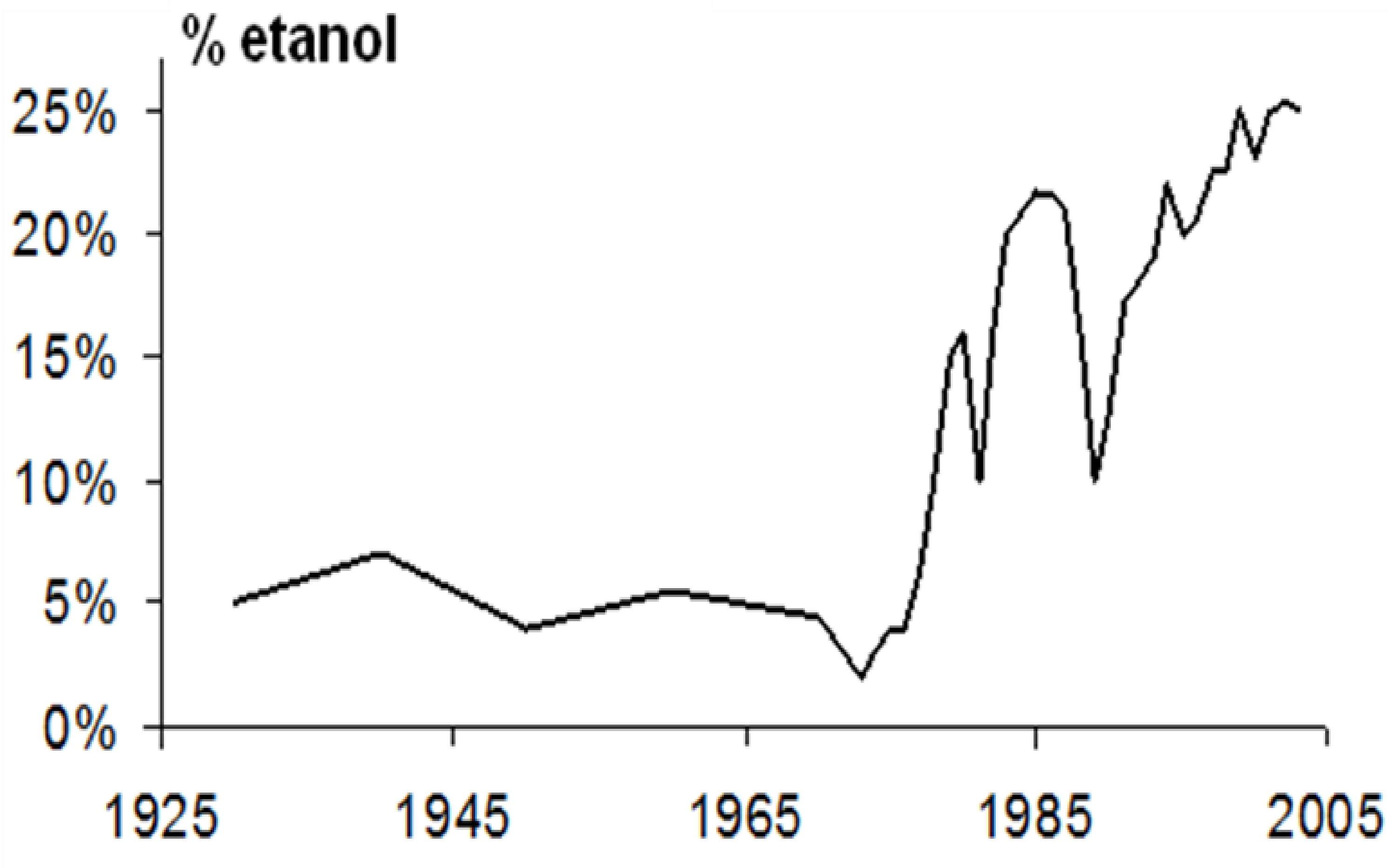
II. The expansion of ethanol consumption

Mandates for the amount of ethanol mixed into the gasoline (25% today).
Setting the price of ethanol paid to the producers at 59% of the selling price of gasoline.

AUTOMOBILE FLEET BRASIL – mid 90’s

In the mid 90’s there were two fleets of automobiles circulating in Brazil:

- Some running on a blend of 20-25% *anhydrous ethanol* at 99.6 Gay-Lussac (GL) and 0.4% water (a mixture called gasohol) and others on
- In neat-ethanol engines in the form of *hydrated ethanol* at 95.5 GL



% etanol
25%
20%
15%
10%
5%
0%
1925
1945
1965
1985
2005

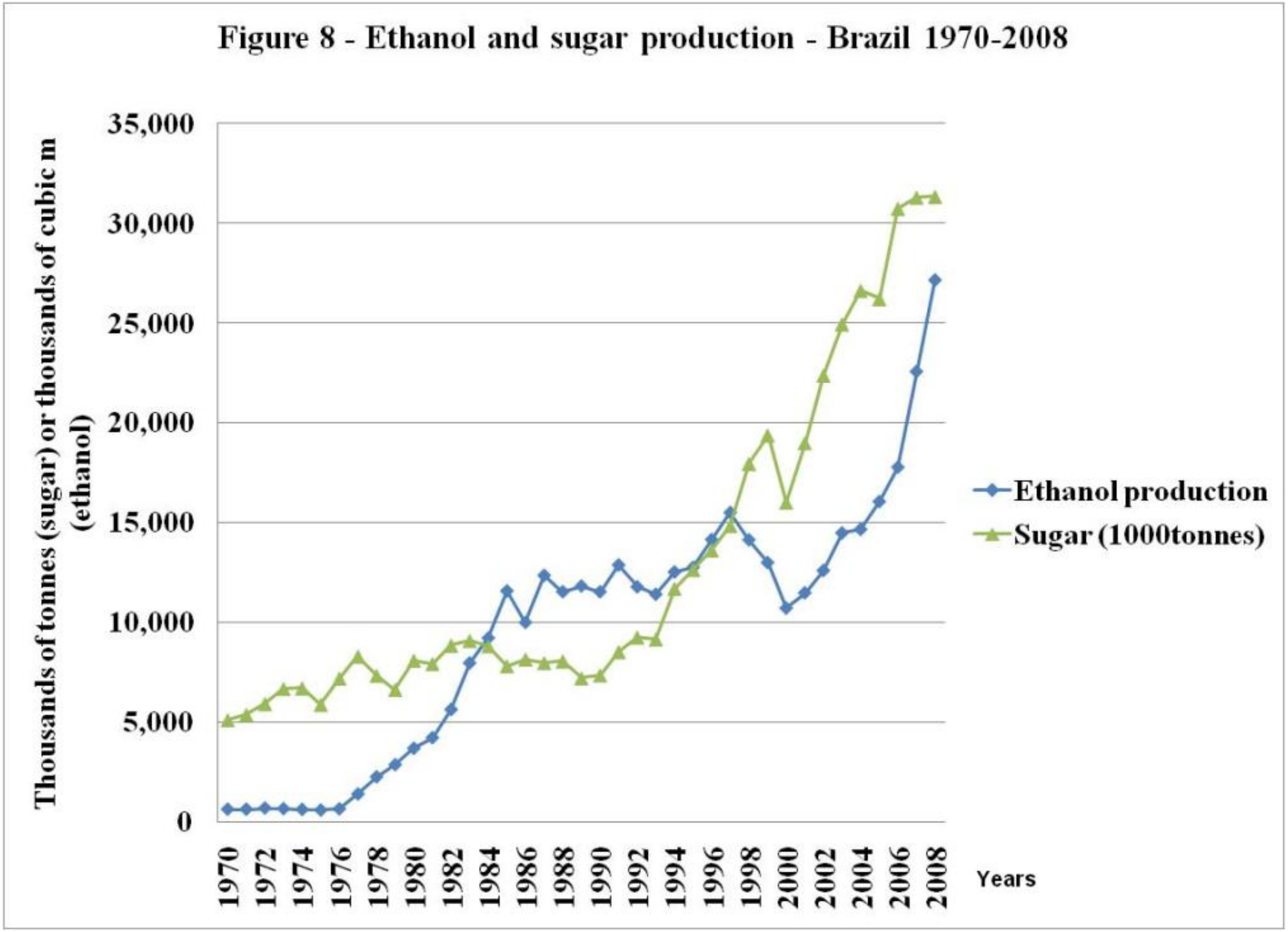
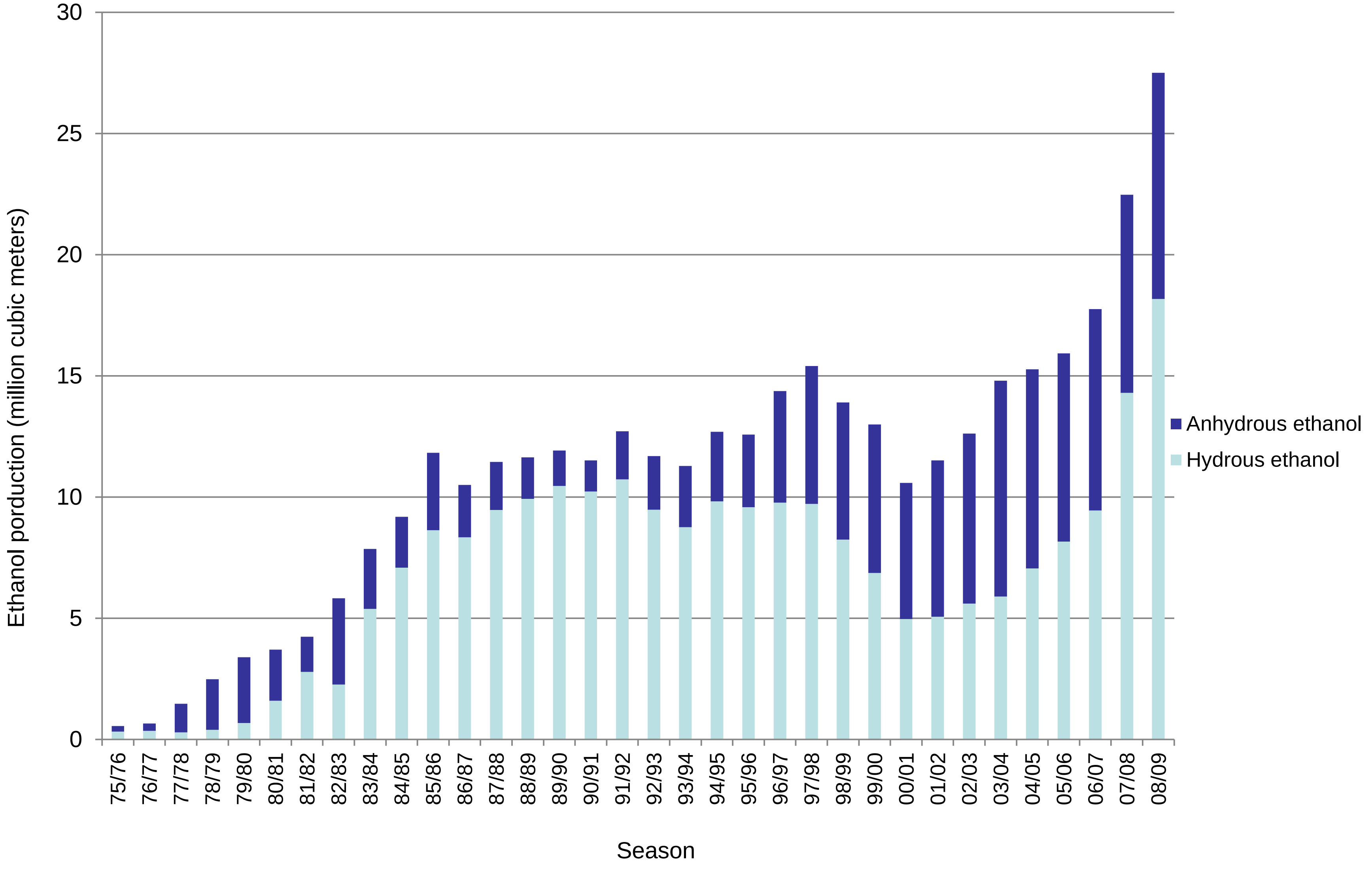
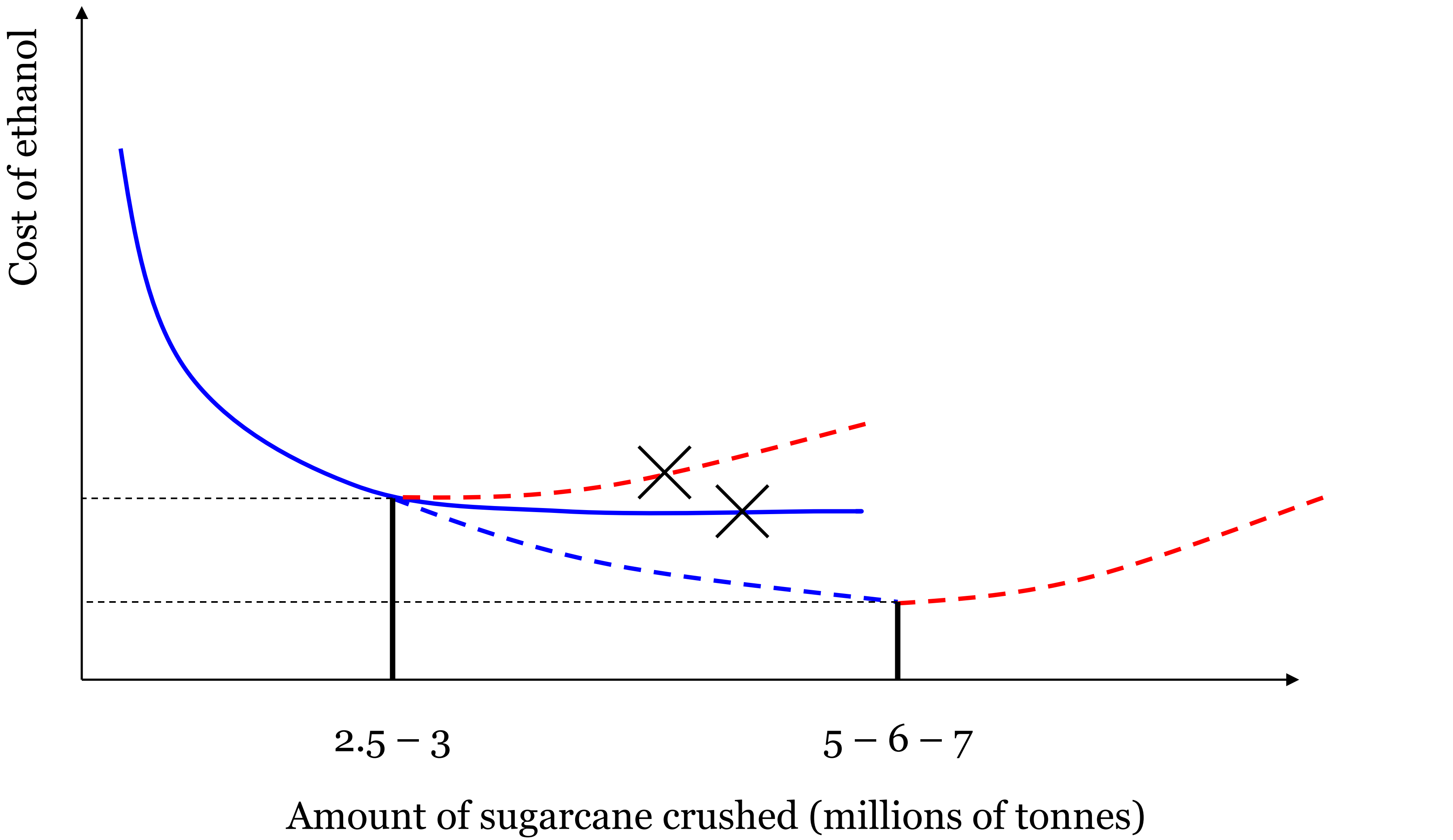


Figure 8 - Ethanol and sugar production - Brazil 1970-2008
Thousands of tonnes (sugar) or thousands of cubic m (ethanol)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
Years
Ethanol production
Sugar (1000tonnes)

Ethanol Production in Brazil



Cost of ethanol as a function of the size of the distillery



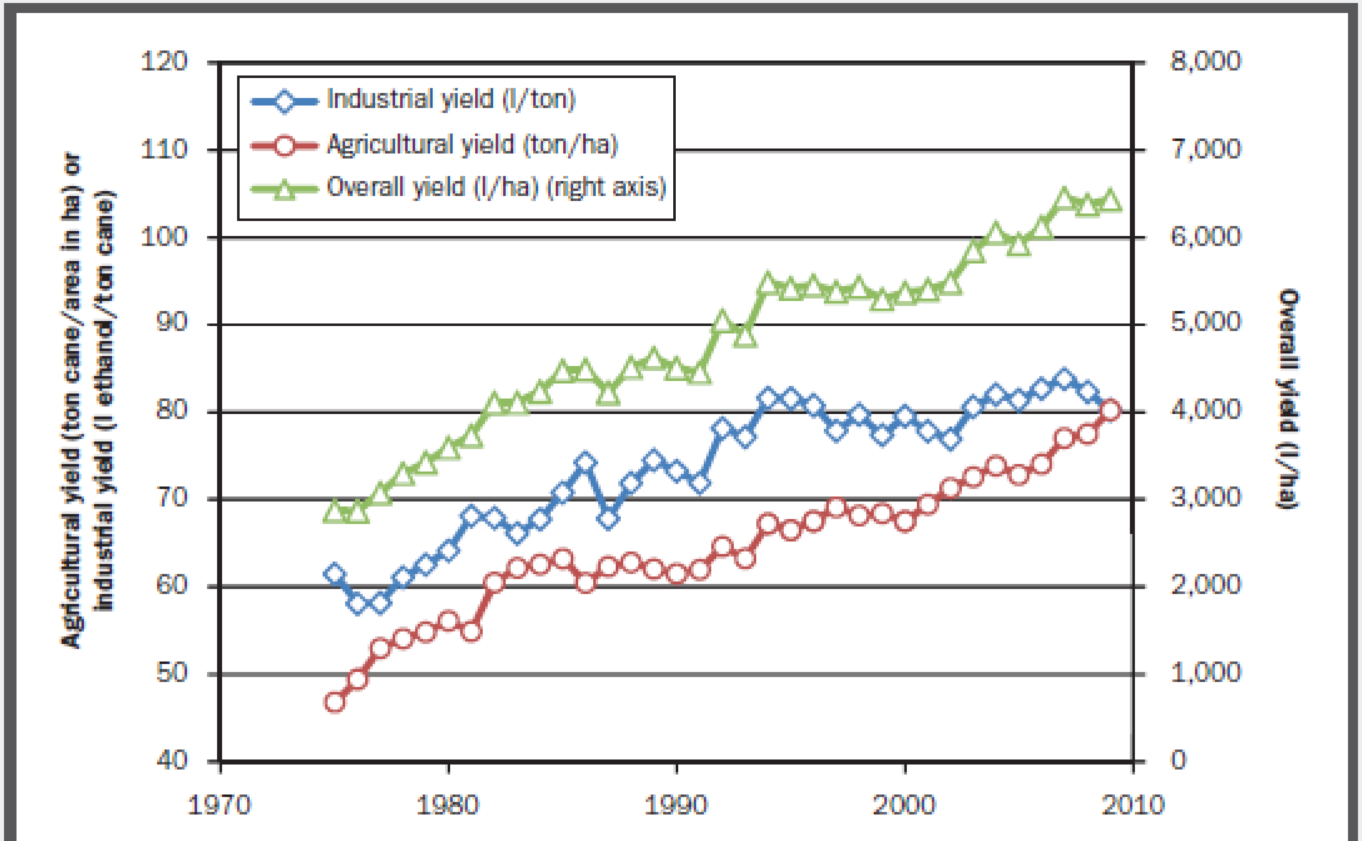
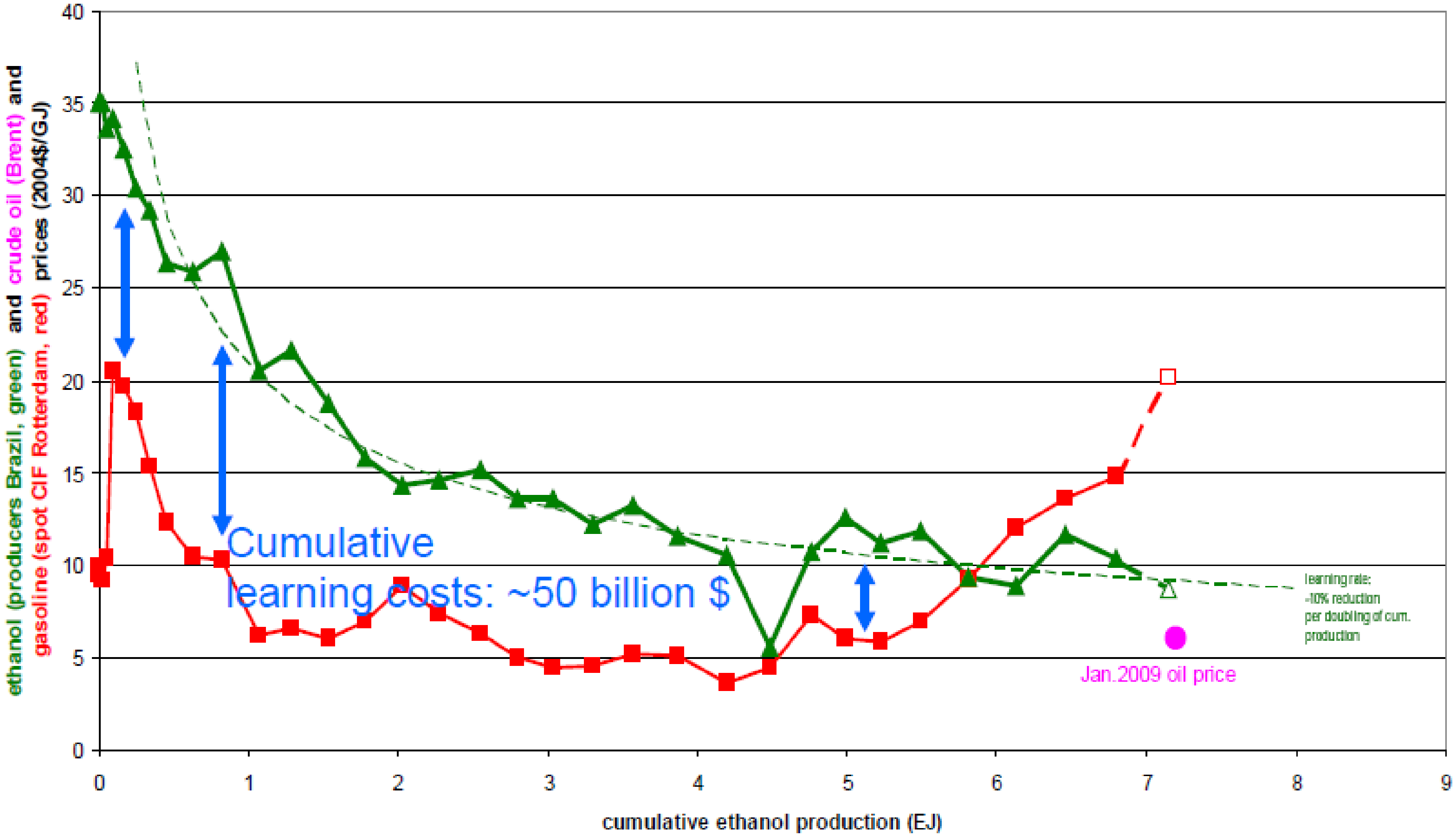


Figure 1 | Average productivity increases in sugar cane and ethanol production in Brazil. The red line shows the agricultural yield in tons of cane per hectare. The blue line shows the industrial yield in litres of ethanol per ton of cane, calculated considering the proportion of total recoverable sugar used for ethanol production. The green line shows the overall yield in litres of ethanol per hectare. Data are from ref. 18.

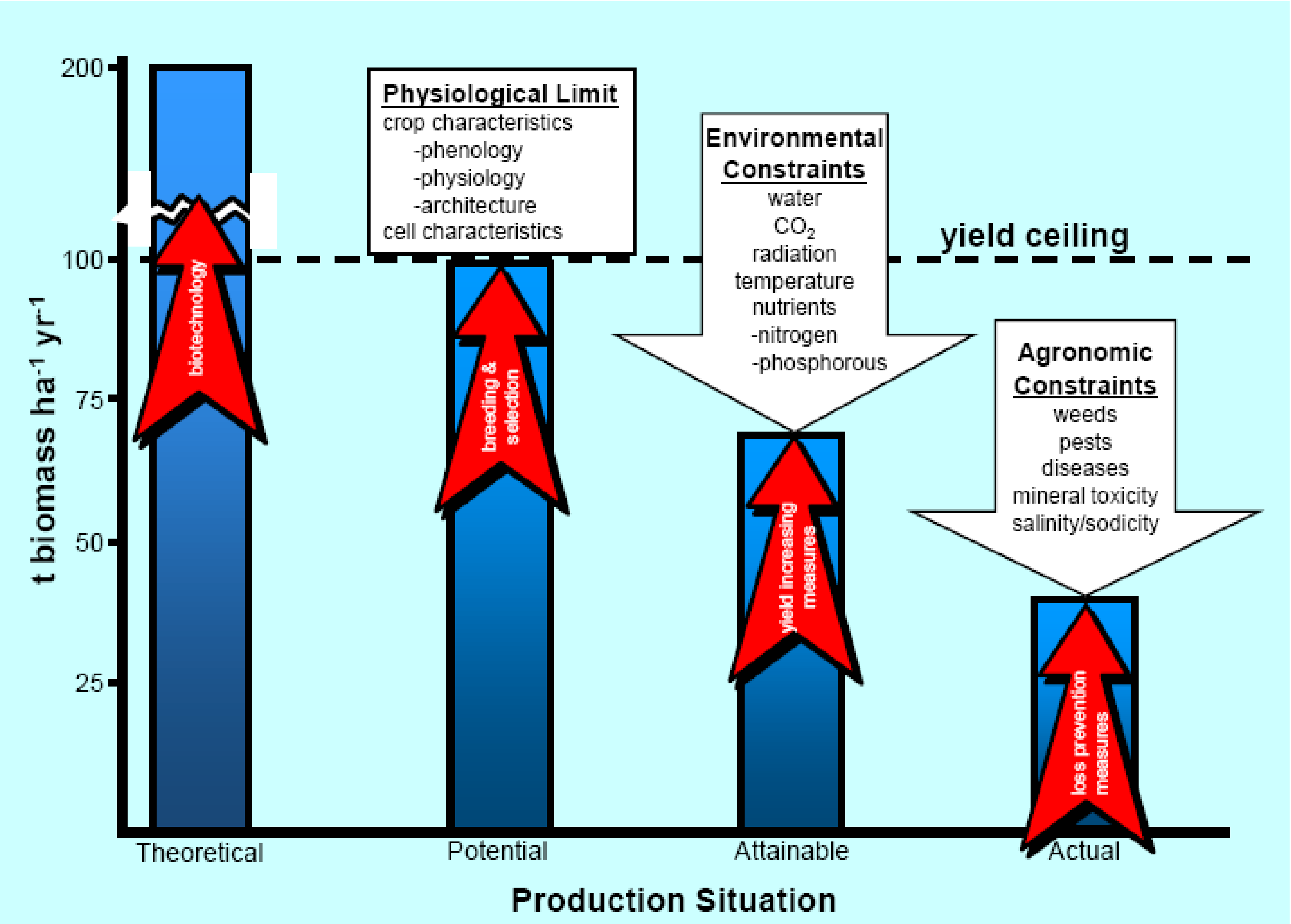


ethanol (producers Brazil, green) and crude oil (Brent) and
gasoline (spot CIF Rotterdam, red) prices (2004$/GJ)
cumulative ethanol production (EJ)
Cumulative
learning costs: ~50 billion $
learning rate:
-10% reduction
per doubling of cum.
production
Jan.2009 oil price
0
5
10
15
20
25
30
35
40
0
1
2
3
4
5
6
7
8
9

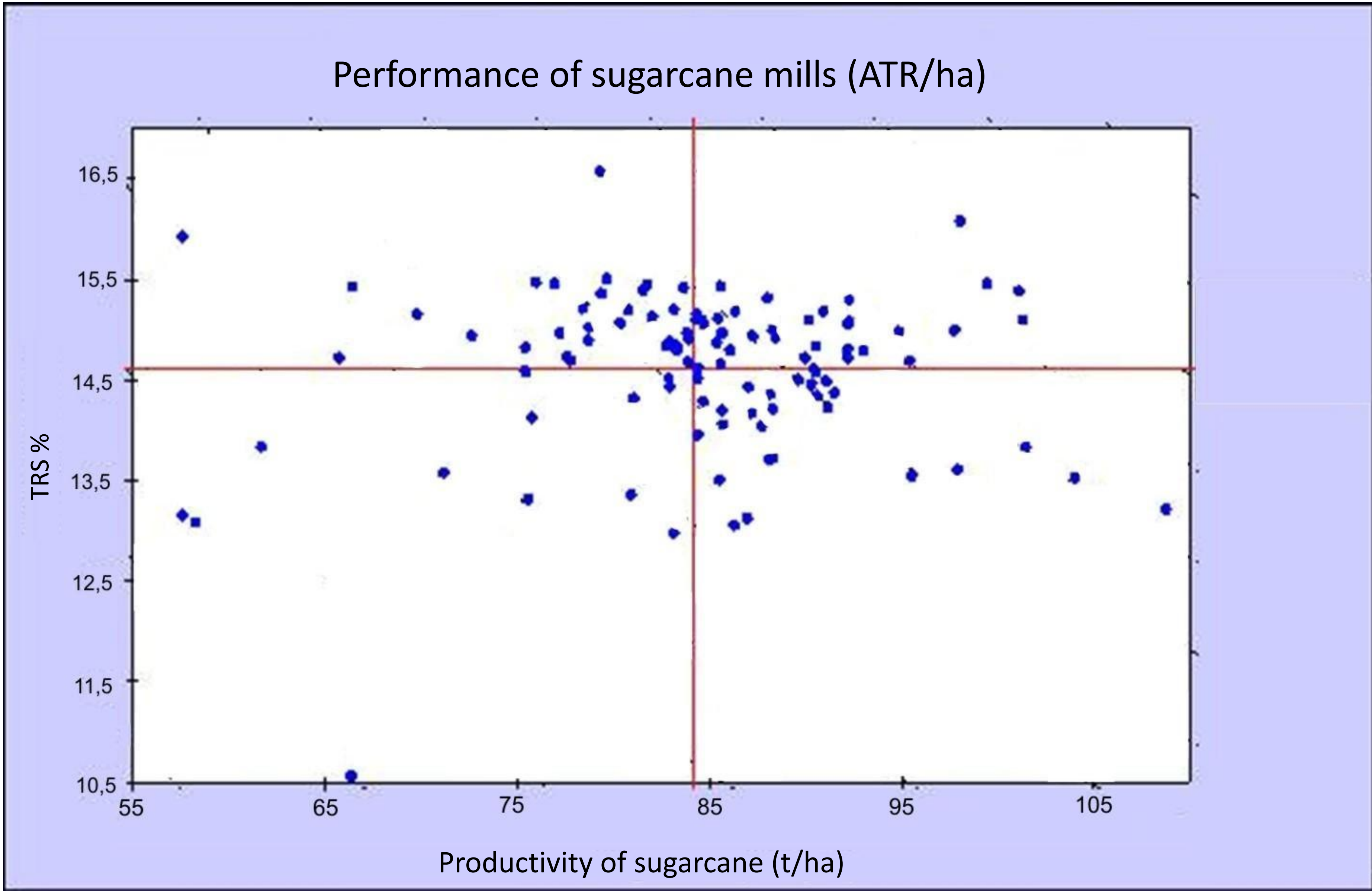
Cost in €/100 liters

	USA (corn)	Germany (wheat)	Germany (sugarbeets)	Brazil (sugarcane)	Rotterdam (gasoline)
Total production cost*	39.47	54.97	59.57	14.48	20
Sale of by products	-6.71	-6.80	-7.20	-	
Government subsidies	-7.93	-	-	-	-
	24-83	48.17	52.37	14.48	20

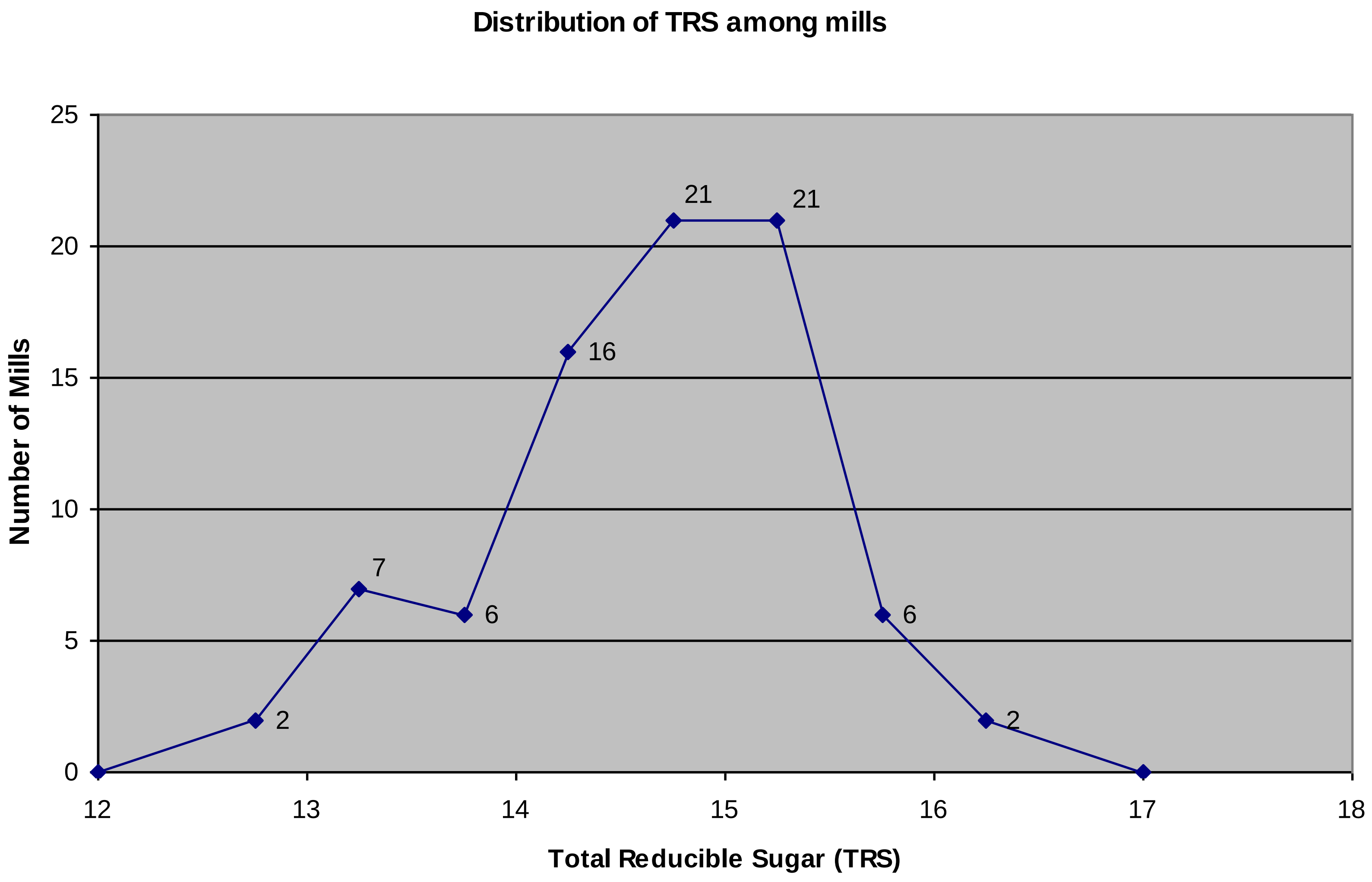
*Feedstock represent in all cases 50 to 70% of total production cost



t biomass ha^{-1} yr^{-1}
200
100
75
50
25
yield ceiling
Physiological Limit
crop characteristics
-phenology
-physiology
-architecture
cell characteristics
Environmental Constraints
water
CO_2
radiation
temperature
nutrients
-nitrogen
-phosphorous
Agronomic Constraints
weeds
pests
diseases
mineral toxicity
salinity/sodicity
biotechnology
breeding & selection
yield increasing measures
loss prevention measures
Theoretical
Potential
Attainable
Actual
Production Situation

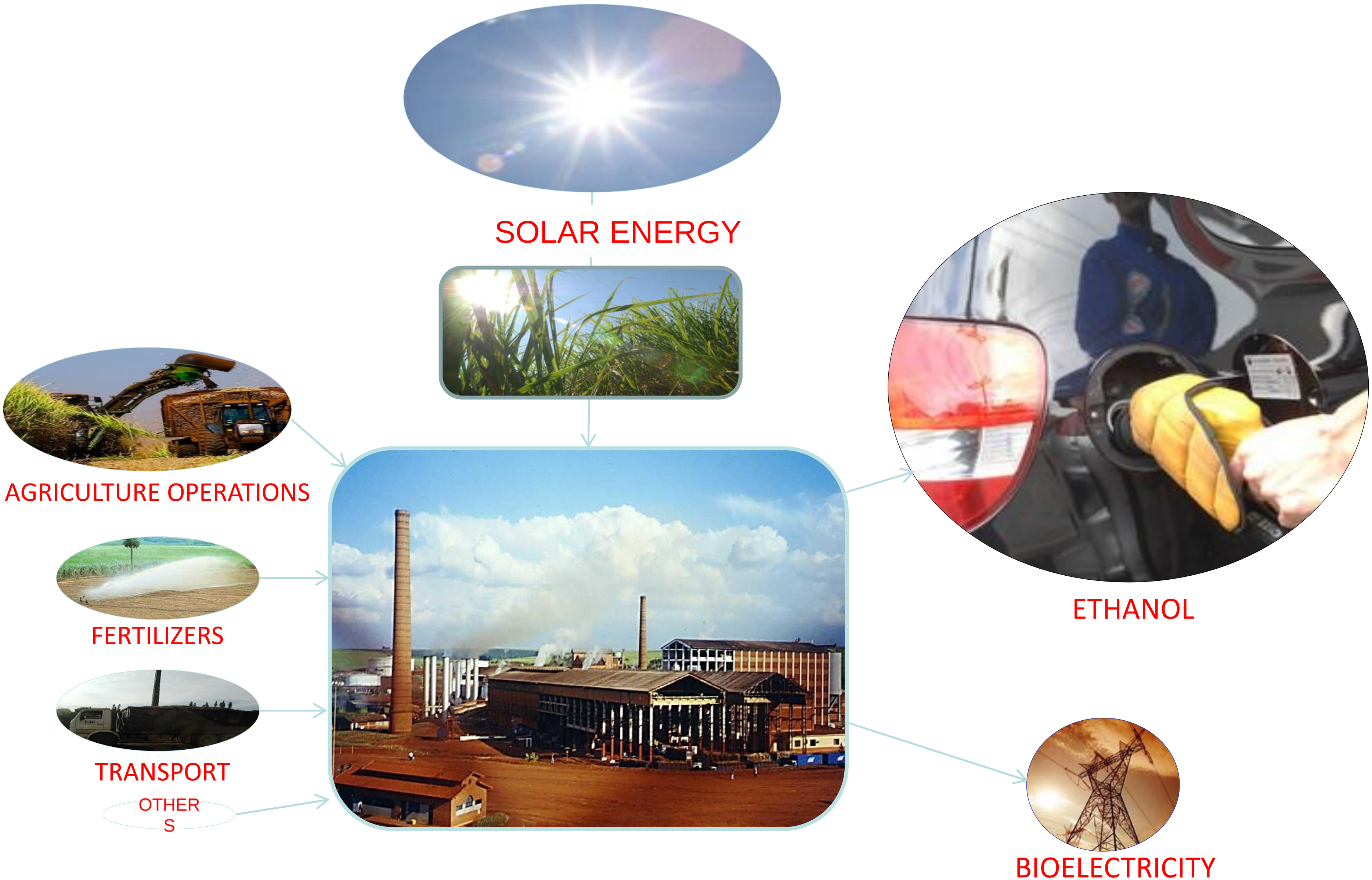


Performance of sugarcane mills (ATR/ha)
16,5
15,5
14,5
13,5
12,5
11,5
10,5
TRS %
55
65
75
85
95
105
Productivity of sugarcane (t/ha)



Distribution of TRS among mills
Number of Mills
Total Reducible Sugar (TRS)
0
5
10
15
20
25
12
13
14
15
16
17
18
2
7
6
16
21
21
6
2

Ethanol Energy Balance



Reprint Series
8 September 1978, Volume 201, pp. 903-906

SCIENCE

Energy Balance for Ethyl Alcohol Production from Crops

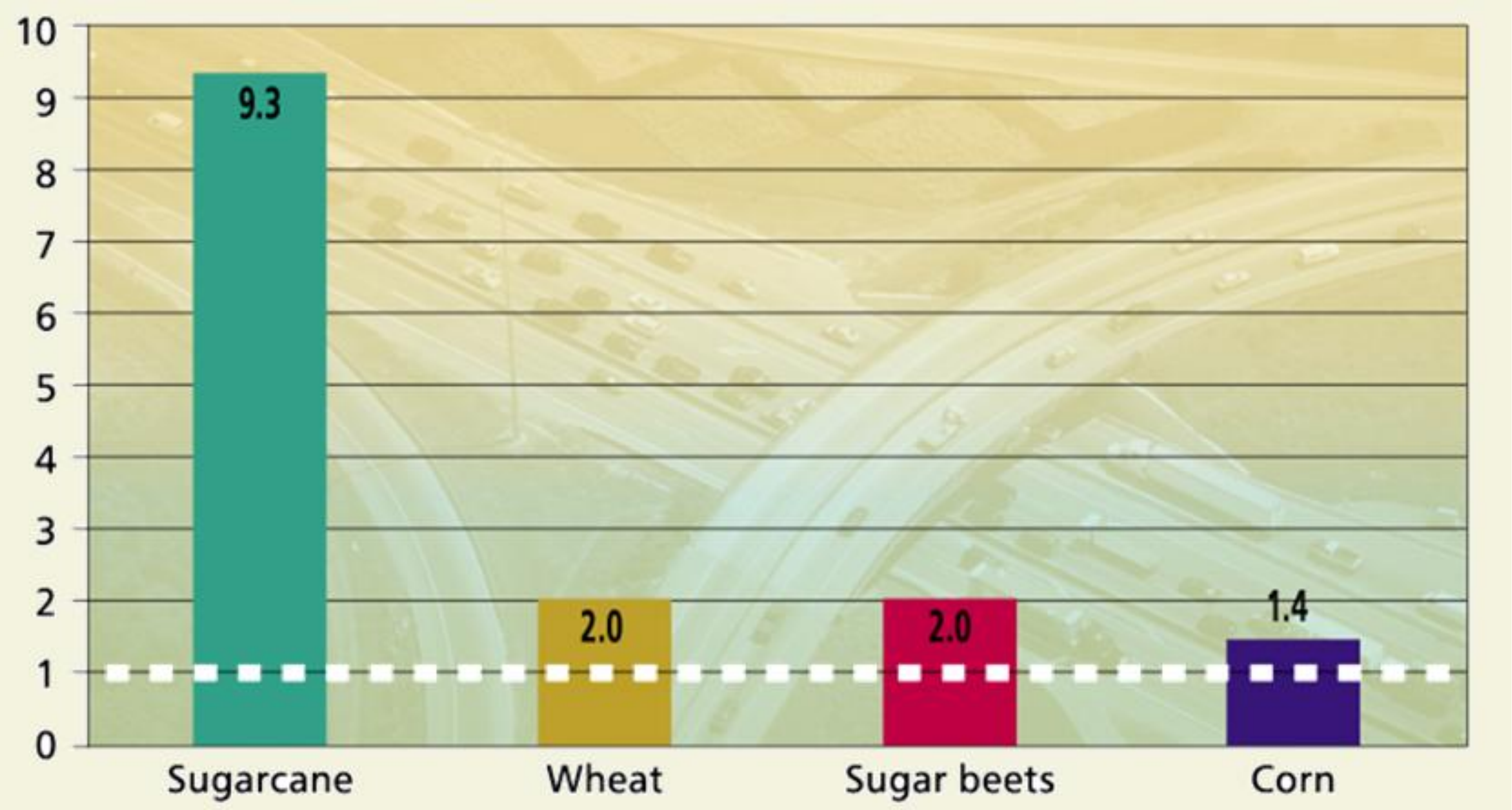
[redacted]

José Gomes da Silva, Gil Eduardo Serra, José Roberto Moreira, José Carlos Gonçalves and José Goldemberg

Energy Balance for Ethyl Alcohol Production from Crops

Abstract. *Energy requirements to produce ethyl alcohol from three different crops in Brazil (sugarcane, cassava, and sweet sorghum) were calculated. Figures are presented for the agricultural and industrial phases. The industrial phase is always more energy-intensive, consuming from 60 to 75 percent of the total energy. Sugarcane is the more efficient crop for ethyl alcohol production, followed by sweet sorghum and cassava from a net energy viewpoint. The utilization of sweet sorghum stems might increase the total energy gain from this crop to almost the same level as sugarcane. Cassava has a lower energy gain at the present state of agriculture in Brazil.*

Energy Balance



Fonte: World Watch Institute (2006) e Macedo et al. (2008).
Elaboração: UNICA

Greenhouse gas emissions

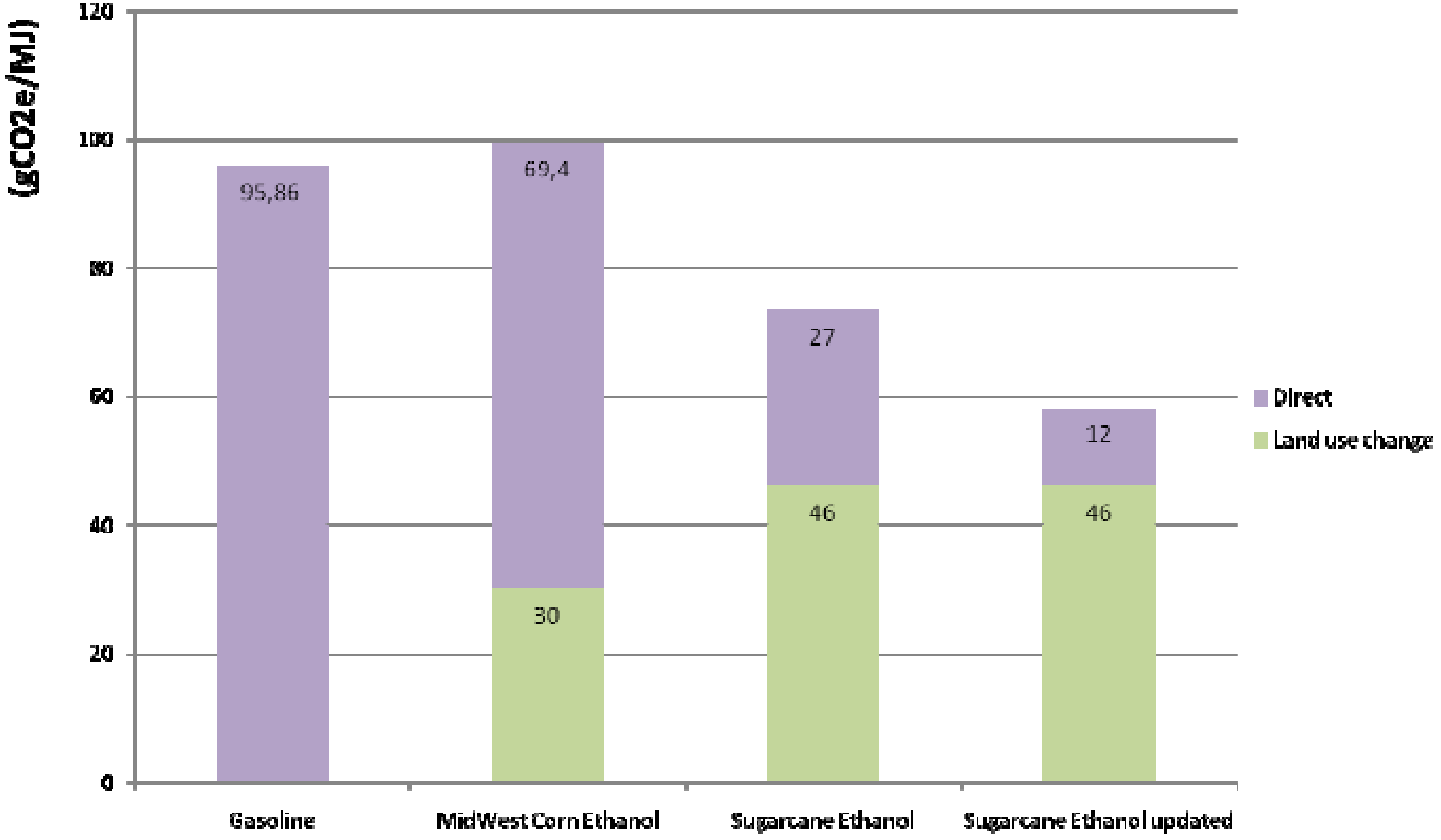


TABLE R12. Biofuels Blending Mandates

NOTE: Data from GSR 2010 – need updating/confirmation; Data in black are updated for 2010.

Country	Mandate
Argentina	B5 by 2010; E5 by 2010
Australia	E2 in New South Wales, increasing to E10 by 2011; E5 in Queensland by 2010
Bolivia	B2.5 by 2007; B20 by 2015; E10
Brazil	B5 by 2010; E20–E25 currently
Canada	E5 by 2010 and B2 by 2012; E5 in Alberta; E7.5 in Saskatchewan; E8.5 in Manitoba; E5 in Ontario; Quebec 5% target by 2012 from advanced biofuels
China	E10 in 9 provinces
Colombia	B10 by 2010 and B20 by 2012; E8 by 2010
Czech Republic	B3.5
Dominican Republic	E15 and B2 by 2015
Ethiopia	E 10 by 2011
Germany	Biofuels share 6.75% by 2010 and 7.25% by 2012; biodiesel 4.4% by 2009; ethanol 2.8% by 2009 and 3.6% by 2015
India	20% blending of biofuels both for bio-diesel and bio-ethanol by 2017
Italy	E1, B1
Jamaica	E10 by 2009
Kenya	E-10 by 2010
Malaysia	B5 by 2008
Mexico	E6.7 by 2010 in Guadalajara, by 2011 in Monterrey, by 2012 in Central Valley
Pakistan	B5 by 2015; B10 by 2025
Paraguay	E18–E24; B5
Peru	B5 by 2011; E7.8 by 2010
Philippines	B2 and E10 by 2011
Portugal	B7 by 2010
South Korea	B3 by 2012
Spain	B5.8 by 2010
Thailand	B3 by 2010; E10
United Kingdom	B3.25
United States	Nationally, 130 billion liters/year by 2022 (36 billion gallons); E10 in Iowa, Hawaii, Missouri, and Montana; E20 in Minnesota; B5 in New Mexico; E2 and B2 in Louisiana and Washington State; 3.4 billion liters/year biofuels by 2017 (0.9 billion gallons) in Pennsylvania
Uruguay	B5 by 2012, less than E5 until 2015, then greater than E5 after 2015

Notes: Table shows binding obligations on fuel suppliers; there are other countries with future indicative targets that are not shown here; see the Biofuels Policies section. Chile had voluntary guidelines for E5 and B5. South Africa had proposed mandates of E8–E10 and B2–B5. Some mandates shown may be delayed by market issues. Mandates in some U.S. states take effect only in future years or under certain future conditions, or apply only to portions of gasoline sold. *Sources:* All available policy references, including the IEA online Global Renewable Energy Policies and Measures database and submissions from report contributors.

Table 12.1 • World biofuels production, 2009

	Ethanol		Biodiesel		Total	
	Mtoe	kb/d	Mtoe	kb/d	Mtoe	kb/d
United States	21.5	470	1.6	33	23.1	503
Brazil	12.8	287	1.2	25	14.1	312
European Union	1.7	38	7.0	140	8.7	178
China	1.1	24	0.3	6	1.4	30
Canada	0.6	13	-	-	0.6	13
India	0.1	3	0.1	2	0.2	5
Other	0.9	20	2.7	51	3.6	72
World	38.7	855	12.9	257	51.6	1 112

Present production and potential demand for ethanol

Country/region	Present gasoline consumption (billion liters per year) 2007	Present ethanol production (billion liters per year) 2008	Potential demand resulting from present mandates up to 2020/22 per year
US	530	34	136
European Union	148	2.3	8.51
China	54	1.9	5.4
Japan	60	0.1	1.8
Canada	39	0.9	1.95
United Kingdom	26	0.03	1.3
Australia	20	0.075	2.0
Brazil	25.2	27	50
South Africa	11.3	0.12	0.9
India	13.6	0.3	0.68
Thailand	7.2	0.3	0.7
Argentina	5.0	0.2	0.25
The Philippines	5.1	0.08	0.26
Total	943.2	67.3	209.75

Gasoline and ethanol in 2025

	2005	2010	2025
Gasoline consumption (x10^{12} liters)	1.2		1.7
Ethanol production (x10^{9} liters)		27	102
Sugarcane area (ha x 10^{6})		45	21

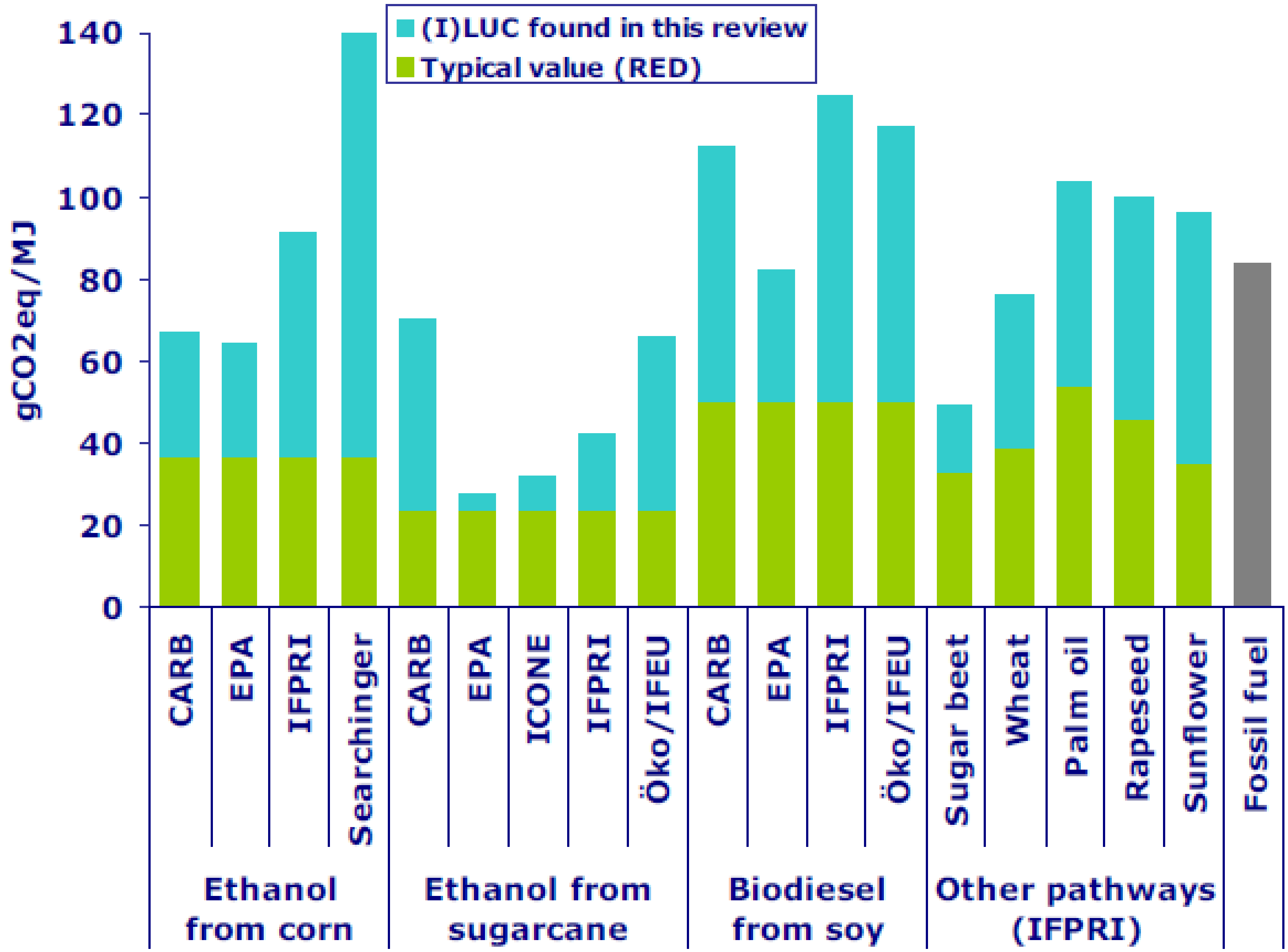


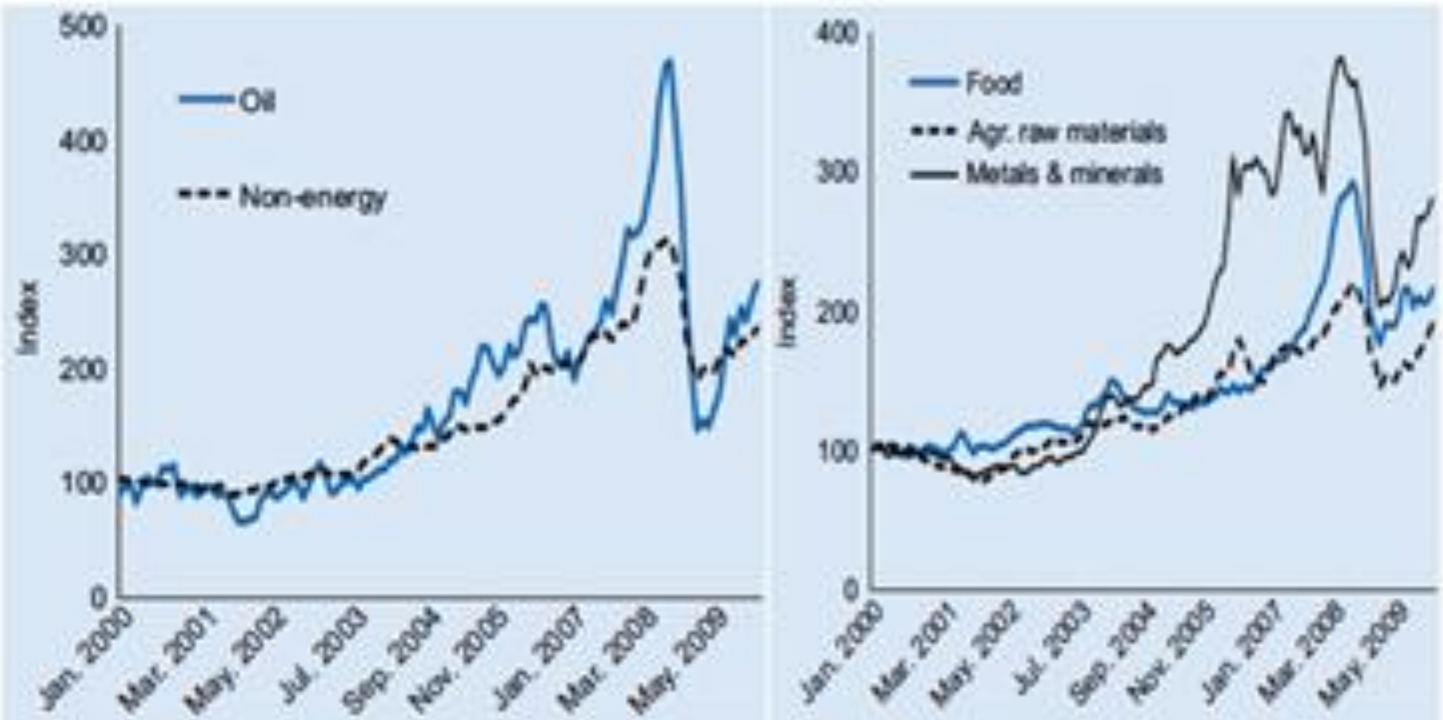
Figure 2 - 2 Graphical representation of the emissions caused by (I)LUC, direct and indirect land use change, for different biofuel pathways and different studies. For reference, typical non-land-use change emissions for the different pathways and a fossil reference from the EU Renewable Energy Directive (RED) have been added.

Fuel “versus” food

When international food prices spiked upward sharply in the spring of 2008 journalists reported that the world was running out of food. Environmentalists asserted that modern agricultural production methods has become unsustainable. Humanitarians warned that too much food was being diverted for use as transport fuel. Others said the problem was too many food imports by China. In fact, none of these popular explanations touched the core of the problem. The international food price spike was part of a temporary bubble in all commodity prices, oil and metals as well food, a macroeconomic effect that was worsened inside the food sector by a series of national export bans and then panic buying triggered by those bans.

Source: FOOD POLITICS What Everyone needs to know. Robert Paarlberg – OXFORD University Press, 2010

Chart 2 – Commodity Price Indexes
Jan 2000 - Nov 2009 (US$ 2000 = 100)



Source: Brahmbhatt & Canuto (2010)

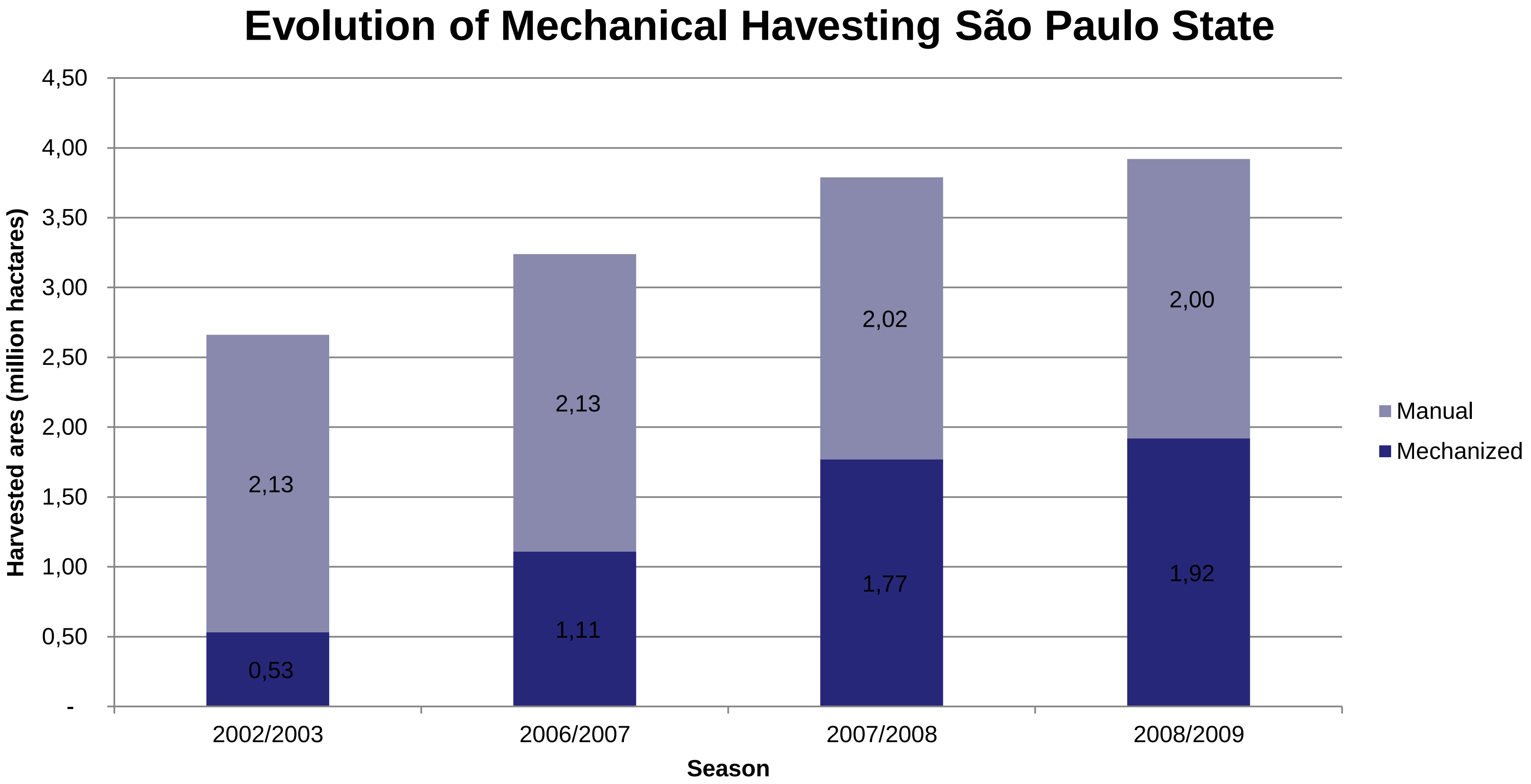
SUSTAINABILITY INITIATIVES FOR BIOFUELS: A "UNIVERSE" IN CONSTANT EXPANSION

Prepared by UNICA. VERSION 5 (August *2010*)

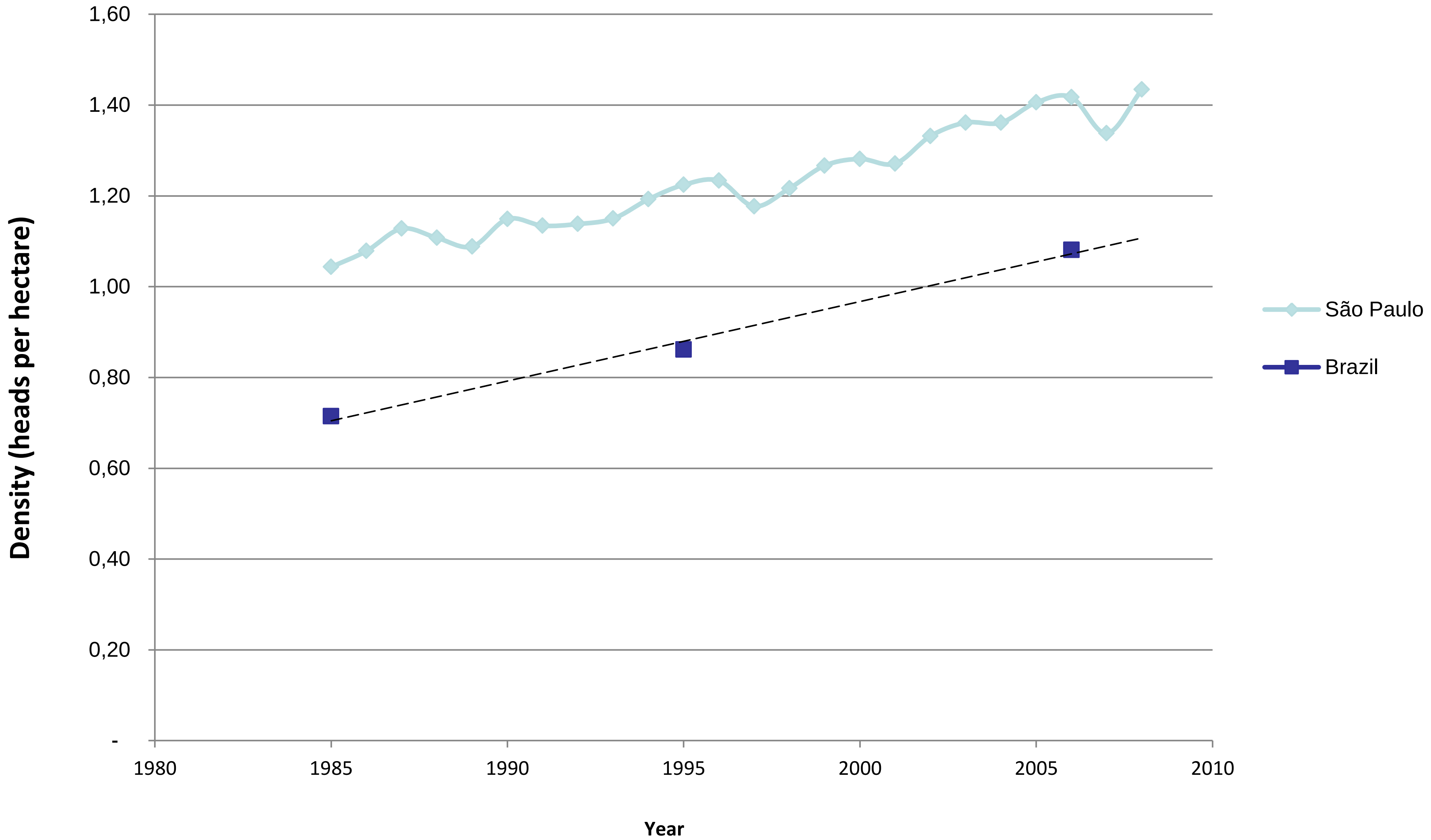
Principle		
1	**Legality**	Biofuel operations shall follow all applicable laws and regulations.
2	**Planning, Monitoring and Continuous Improvement**	Sustainable biofuel operations shall be planned, implemented, and continuously improved through an open, transparent, and consultative impact assessment and management process and an economic viability analysis.
	2a.	Biofuel operations shall undertake an impact assessment process to assess impacts and risks and ensure sustainability through the development of effective and efficient implementation, mitigation, monitoring and evaluation plans.
	2b.	Free, Prior & Informed Consent (FPIC) shall form the basis for the process to be followed during all stakeholder consultation, which shall be gender sensitive and result in consensus-driven negotiated agreements.
3	**Greenhouse Gas Emissions**	Biofuels shall contribute to climate change mitigation by significantly reducing lifecycle GHG emissions as compared to fossil fuels.
4	**Human and Labor Rights**	Biofuel operations shall not violate human rights or labor rights, and shall promote decent work and the well-being of workers.
5	**Rural and Social Development**	In regions of poverty, biofuel operations shall contribute to the social and economic development of local, rural and indigenous people and communities.
6	**Local Food Security**	Biofuel operations shall ensure the human right to adequate food and improve food security in food insecure regions.
7	**Conservation**	Biofuel operations shall avoid negative impacts on biodiversity, ecosystems, and conservation values.
8	**Soil**	Biofuel operations shall implement practices that seek to reverse soil degradation and/or maintain soil health.
9	**Water**	Biofuel operations shall maintain or enhance the quality and quantity of surface and ground water resources, and respect prior formal or customary water rights.
10	**Air**	Air pollution from biofuel operations shall be minimized along the supply chain.
11	**Use of Technology, Inputs, and Management of Waste**	The use of technologies in biofuel operations shall seek to maximize production efficiency and social and environmental performance, and minimize the risk of damages to the environment and people.
12	**Land Rights**	Biofuel operations shall respect land rights and land use rights.

Sugar Cane Buring Phase-Out

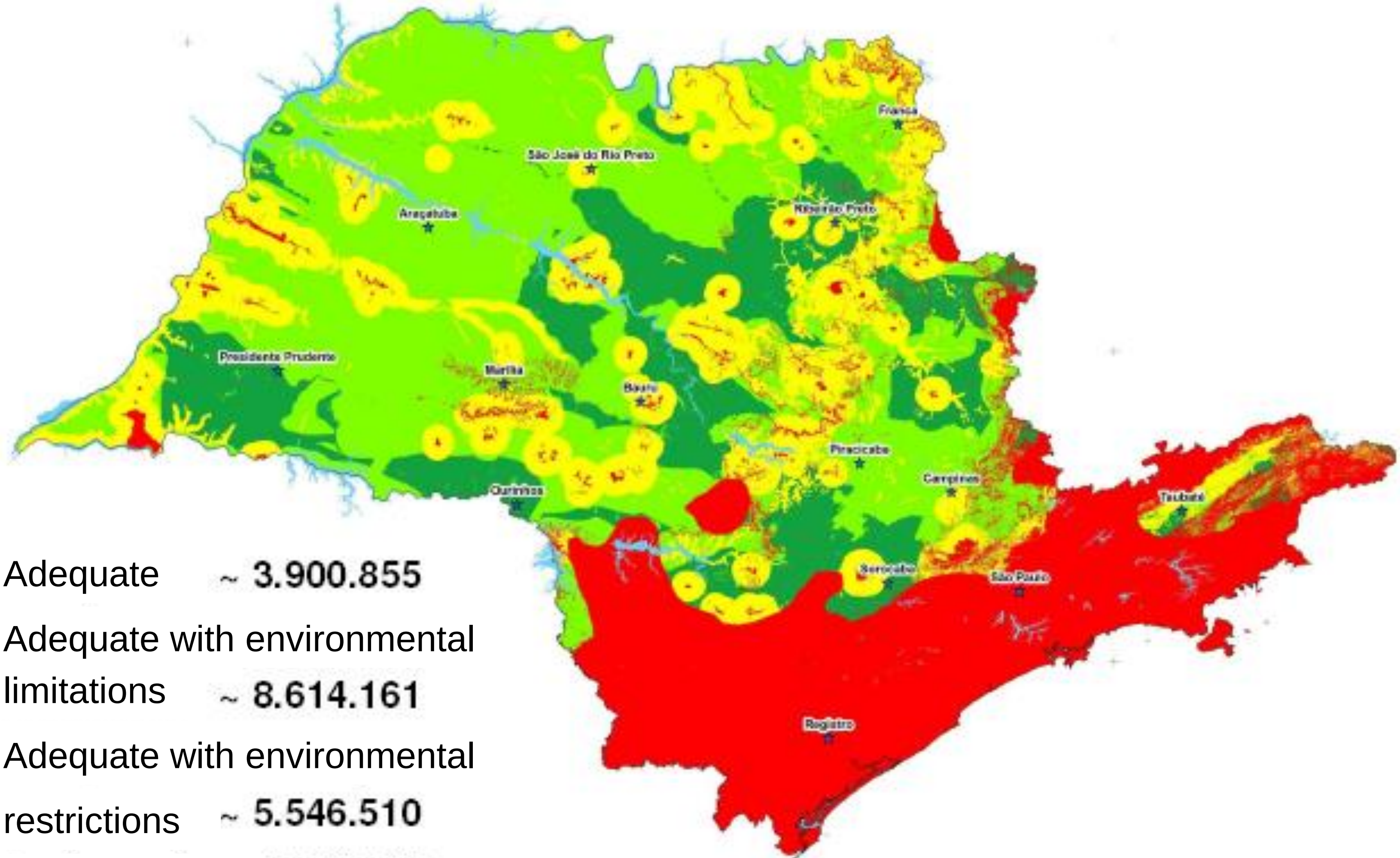
- Established by State Law 11.241/2002
  - Mechanizable areas: year 2021
  - Non-mechanizable areas: year 2031



Evolution of Cattle Ranching Intensification in Brazil and the State of São Paulo



Agroecological zoning for the State of São Paulo



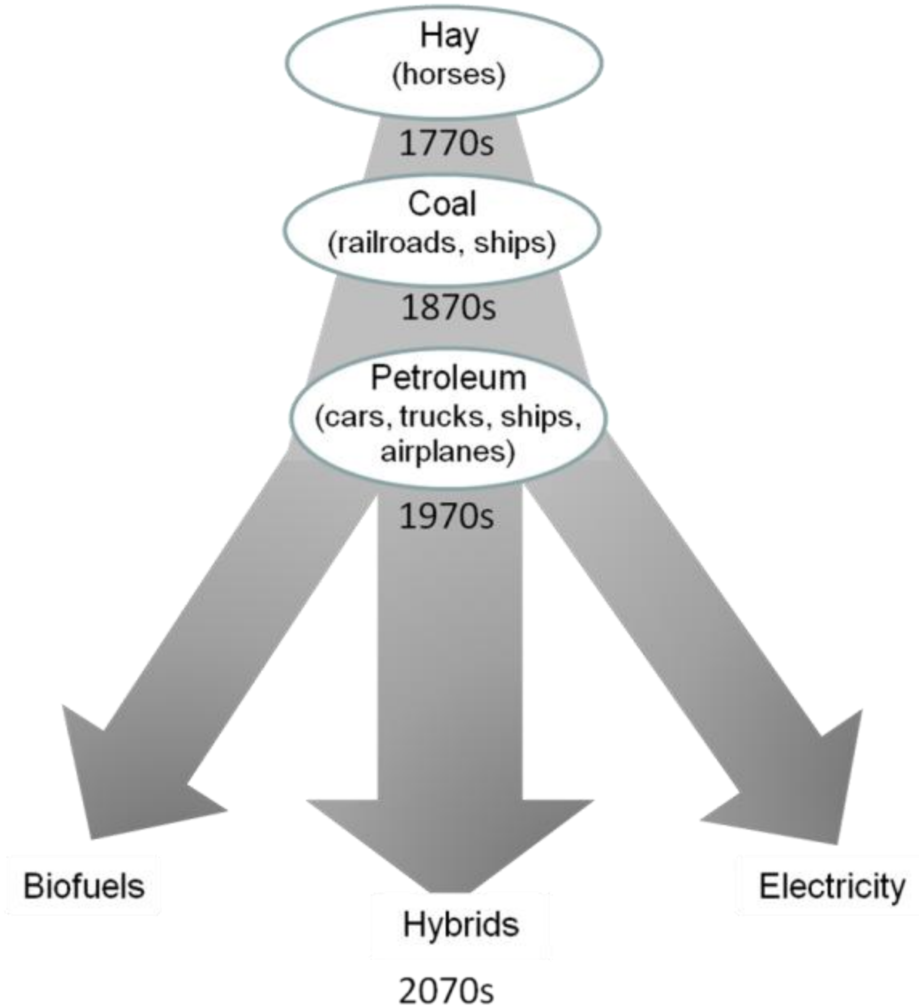
Adequate ~ 3.900.855

Adequate with environmental limitations ~ 8.614.161

Adequate with environmental restrictions ~ 5.546.510

Inadequate ~ 6.741.748

The Evolution of Transportation



Liquids supply

Millions of oil-equivalent barrels per day