How much biofuel can be produced in the World?

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http://bioenfapesp.org

Rationale

- Global Climate Change: Reducing GHG emissions
- Scarcity of resources
  - Oil is finite, expensive and "complicated"
- Energy security (as Food Security)
  - Each nation would like to generate its own energy, or at least most of it, or at least as much as possible of it while not having to pay too much for the rest and having a secure source

330 GL of Ethanol will substitute for 10% of the world's gasoline in 2050

	2004	2050
Gasoline consumption	1,200 GL	2,200 GL
Ethanol consumption	30 GL	55 GL
Energy substitution	1.7 %	1.7 %
Ethanol for 10% energy substitution	180 GL	330 GL

2050: Available land for biofuels

(Doornbosch and Steenblik, 2007)

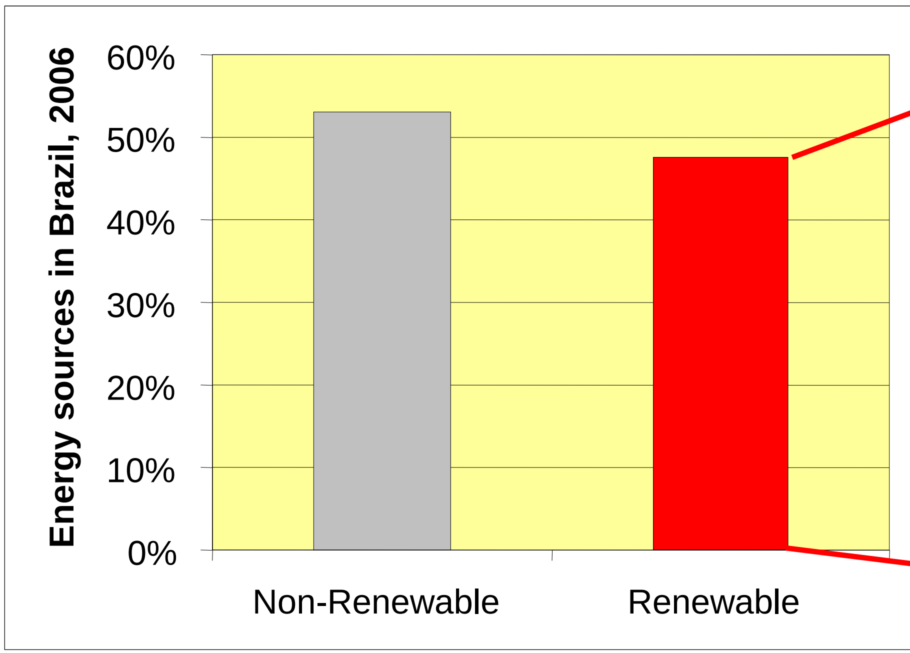
	Land (in Gha)	North Am.	South & Centr. Am.	Europe & Russia	Africa	Asia	Oceania	World
	Total land surface	2,1	2,0	2,3	3,0	3,1	0,9	13,40
1	Apt for Rainfed cultivation	0,4	0,9	0,5	0,9	0,5	0,1	3,30
2	Apt and Under forest	0,1	0,3	0,1	0,1	0,0	0,0	0,80
3	Apt, already in use	0,2	0,1	0,2	0,2	0,6	0,1	1,50
4	Necessary for food, housing and infrastructure until 2030/50	0,0	0,1	0,0	0,1	0,1	0,0	0,30
5	Available (Gross) [5=1-2-3-4]	0,00	0,25	0,08	0,44	-0,07	0,04	0,74
6	% for grassland	0%	0%	50%	60%	n/a	0%	
7	**Additional land potentially available (7)=(5)x(1-% for grassland)**	**0,00**	**0,25**	**0,04**	**0,18**	**-0,07**	**0,04**	**0,44**

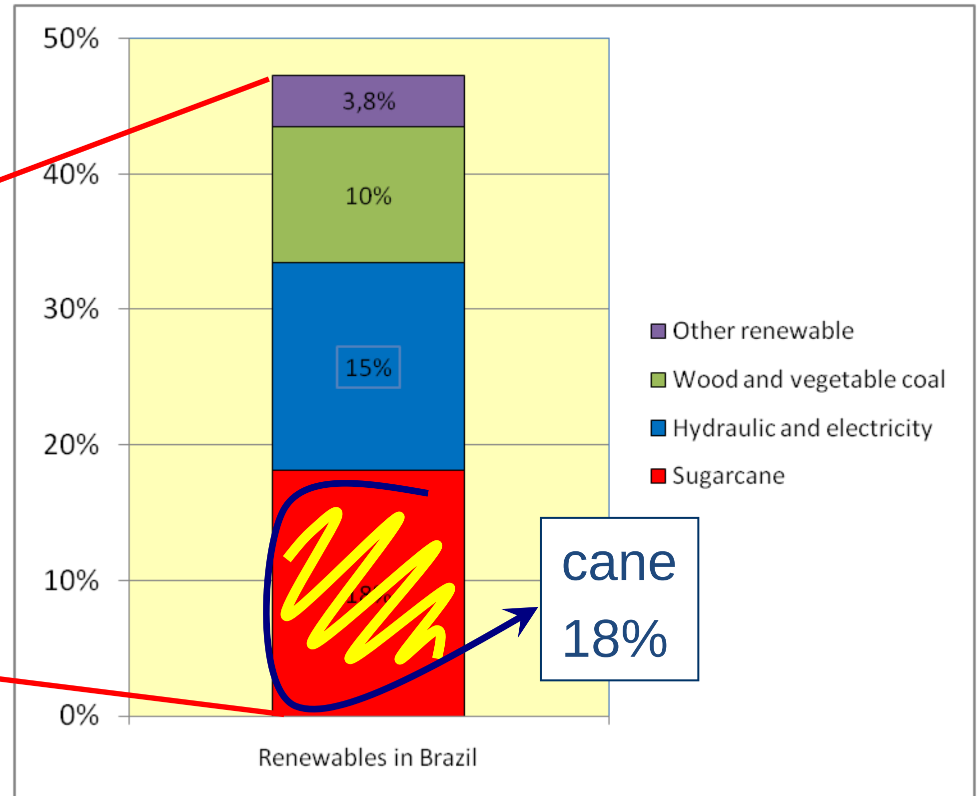
a. Most studies assume that only a small fraction of additional land is needed to feed the world's growing population — from 6.5 billion people at present to 9 billion people in 2050 — and that most of the increase in food requirements will be met by an increase in agricultural productivity.6 Here it is assumed that 0.2 Gha is needed for additional food production (based on Fisher and Schrattenholzer, 2001 where a yearly increase in agricultural productivity of 1.1% is assumed); the remainder (roughly 0.1 Gha) is needed for additional housing and infrastructure.

b. A negative number is shown here as more land is cultivated than potentially available for rain-fed cultivation because of irrigation. The negative land available has not been rounded to zero because food imports are likely to be needed from other region with implications on their land use.

c. Numbers in this column don't add up because of rounding.

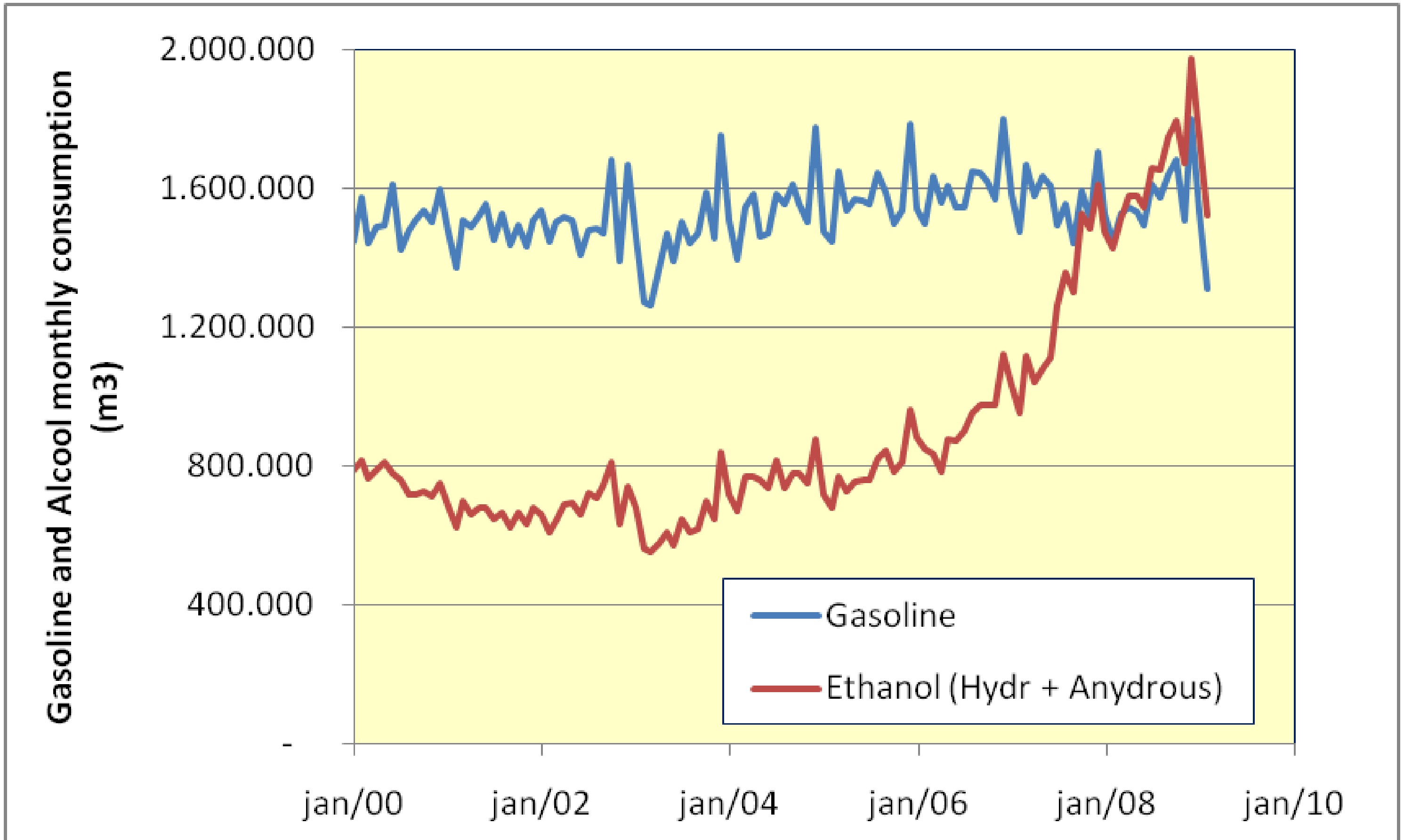
47% of Brazil's energy comes from renewable sources (2009)





Renewables in Brazil: 47%; World: 13%; OECD: 7,2%

Ethanol and Gasoline use in Brazil

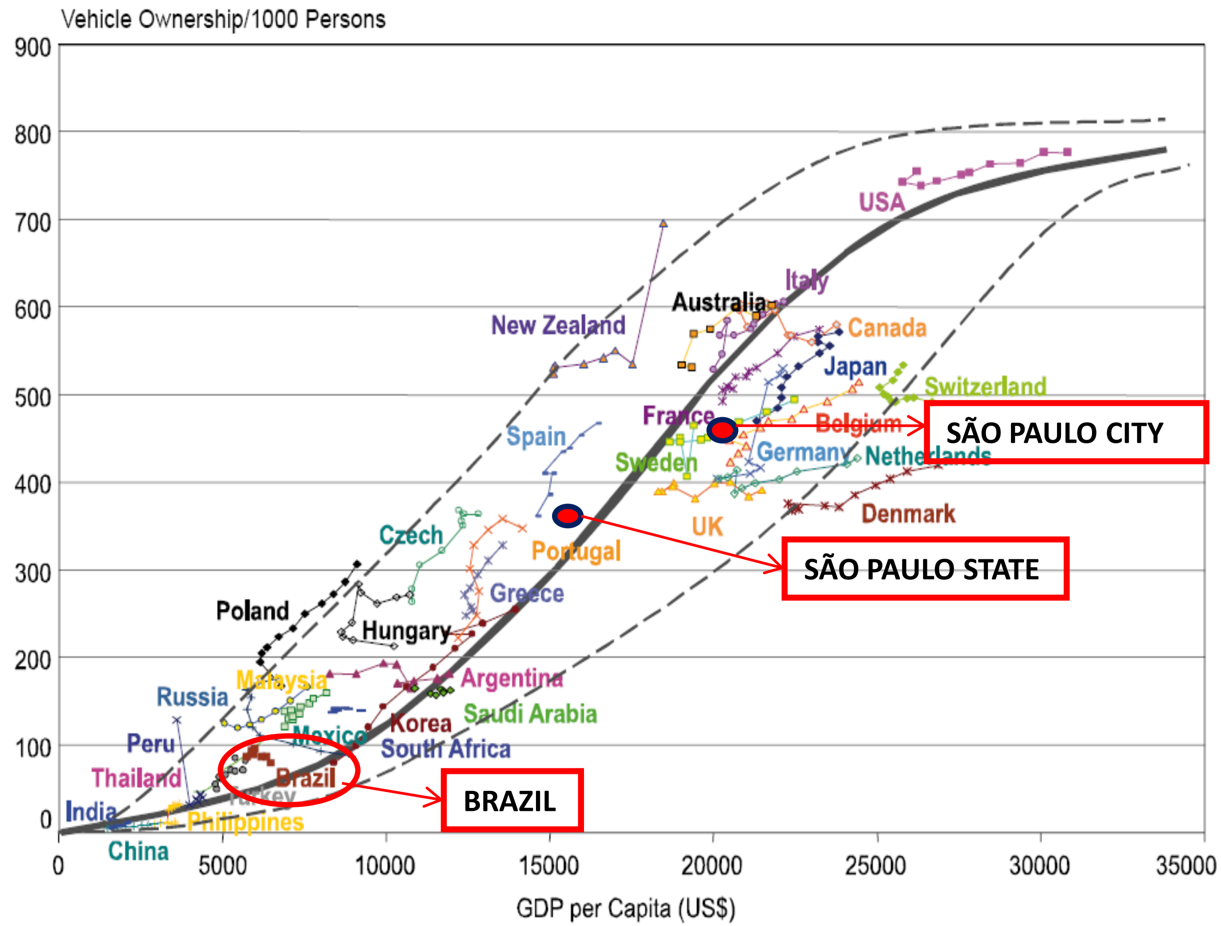


Source: ANP, 2009 and author tabulations

State of São Paulo, Brasil

34% of Brazil's GNP
41 million people
350 vehicles/1000 people
52% of Brazilian science
13% of State budget to HE and R&D
1,6% GNP for R&D

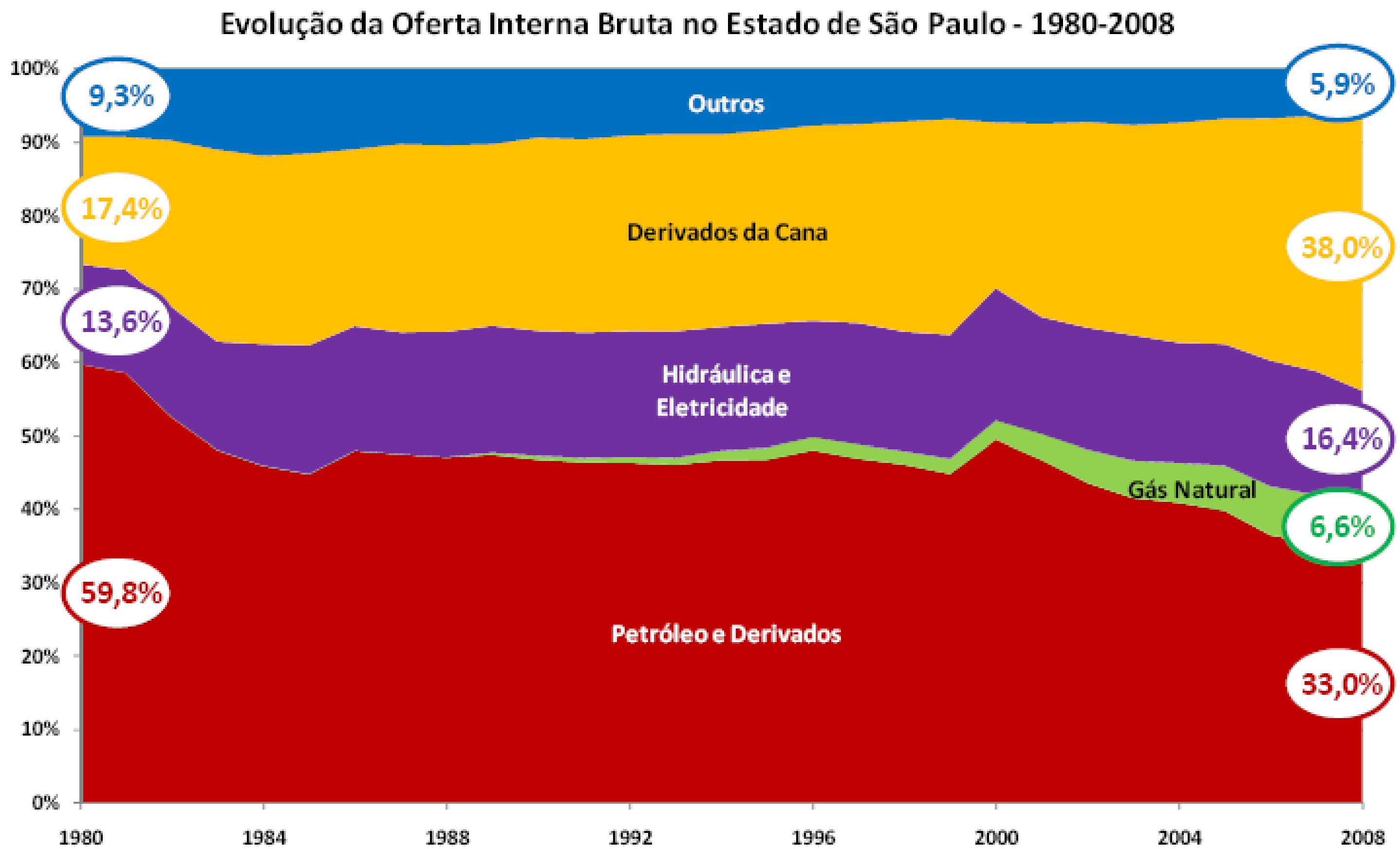
Vehicles per population



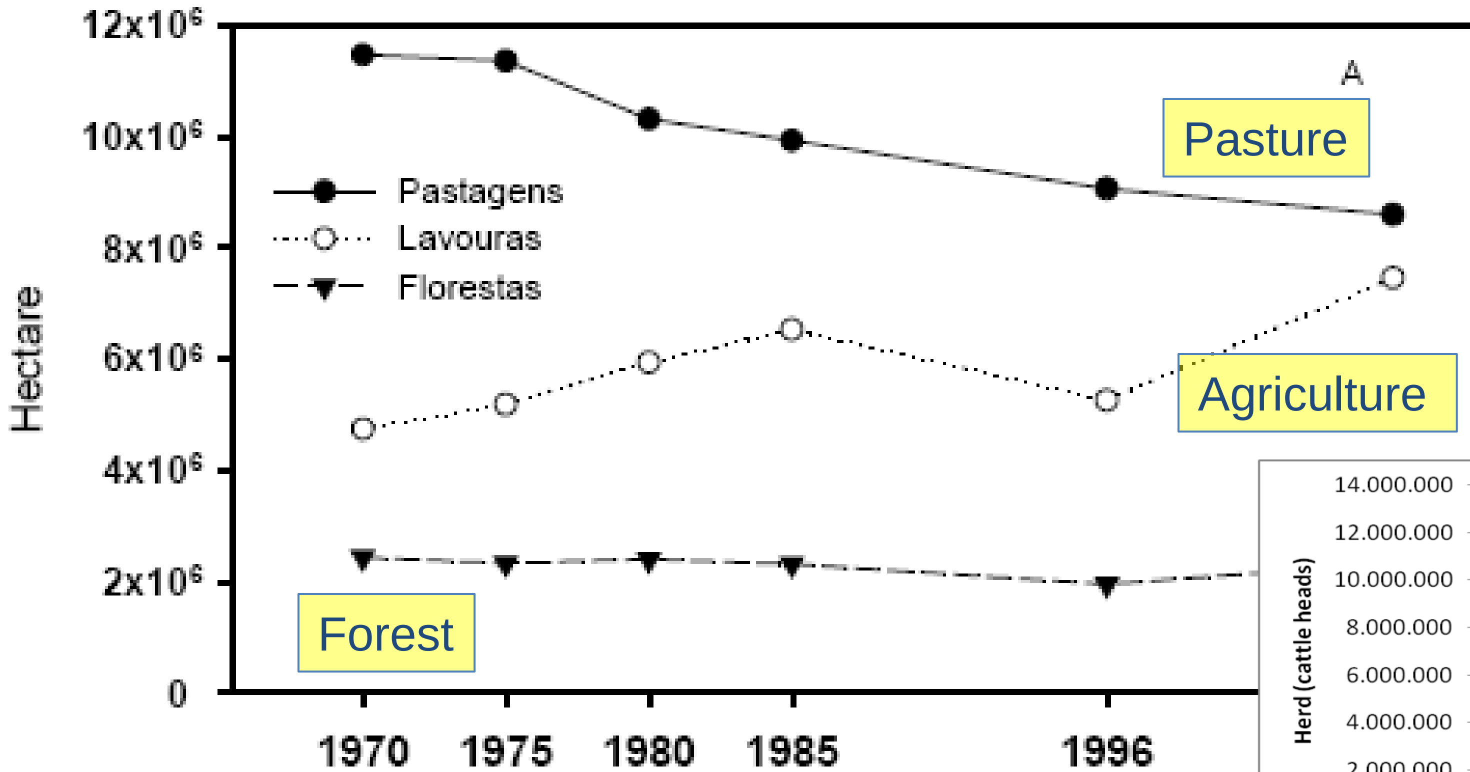
Energy sources in the State of São Paulo, Brazil

State of São Paulo
- 63% of Brazilian ethanol
- 41 million people
- 35% of Brazil's GNP

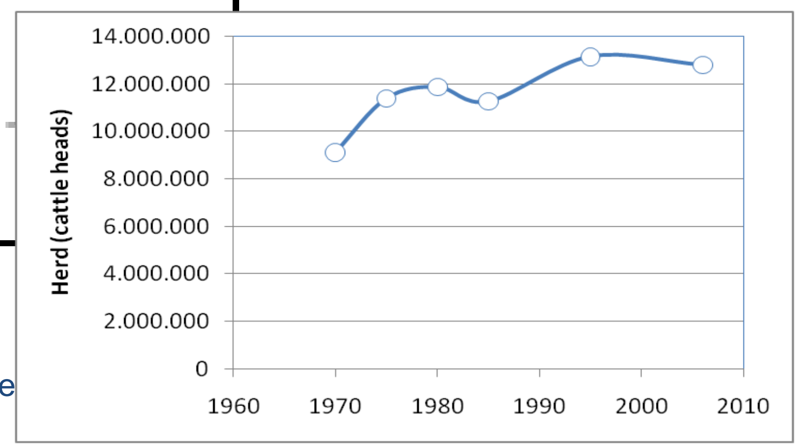
1980 – 2008
- Oil down from 60% to 33%
- Cane up from 17% to 38%



São Paulo: Land Use Change, 1970-2006



Sugarcane x Pasture: fixation of 0,5 Mg C/ha.yr



Source: Boddey, R.M, “GHG Emission Mitigation Though Ethanol from Sugarcane

Brazil: 1,5% of arable land displaces 41%+ of the gasoline

Millions of hectares		% of Brazil	% of Arable Land
BRAZIL	851.4		
TOTAL ARABLE LAND	329.9		
1. Crop Land - Total	59.8	7.0%	18.1%
Soybean	21.6	2.5%	6.4%
Corn	14.4	1.7%	4.4%
Sugarcane	8.1	0.9%	2.5%
Sugarcane for ethanol	4.8	0.6%	1.5%
2. Pasture Land	158.7	18.6%	48.1%
3. Protected Areas and Native Vegetation	495.6	58.2%	-
4. Available Area	137.2	16.1%	-

Source: UNICA, with data from IBGE 2006

Sugarcane productivity gain: present and potential yield

Type of yield	Cane yield ($t\ ha^{-1}\ yr^{-1}$)	Biomass*	
		($t\ ha^{-1}\ yr^{-1}$)	($g\ m^{-2}\ d^{-1}$)
Commercial Average	84	39	10.7
Commercial maximum	148	69	18.8
Experimental maximum	212	98	27.0
Theoretical maximum	381	177	48.5

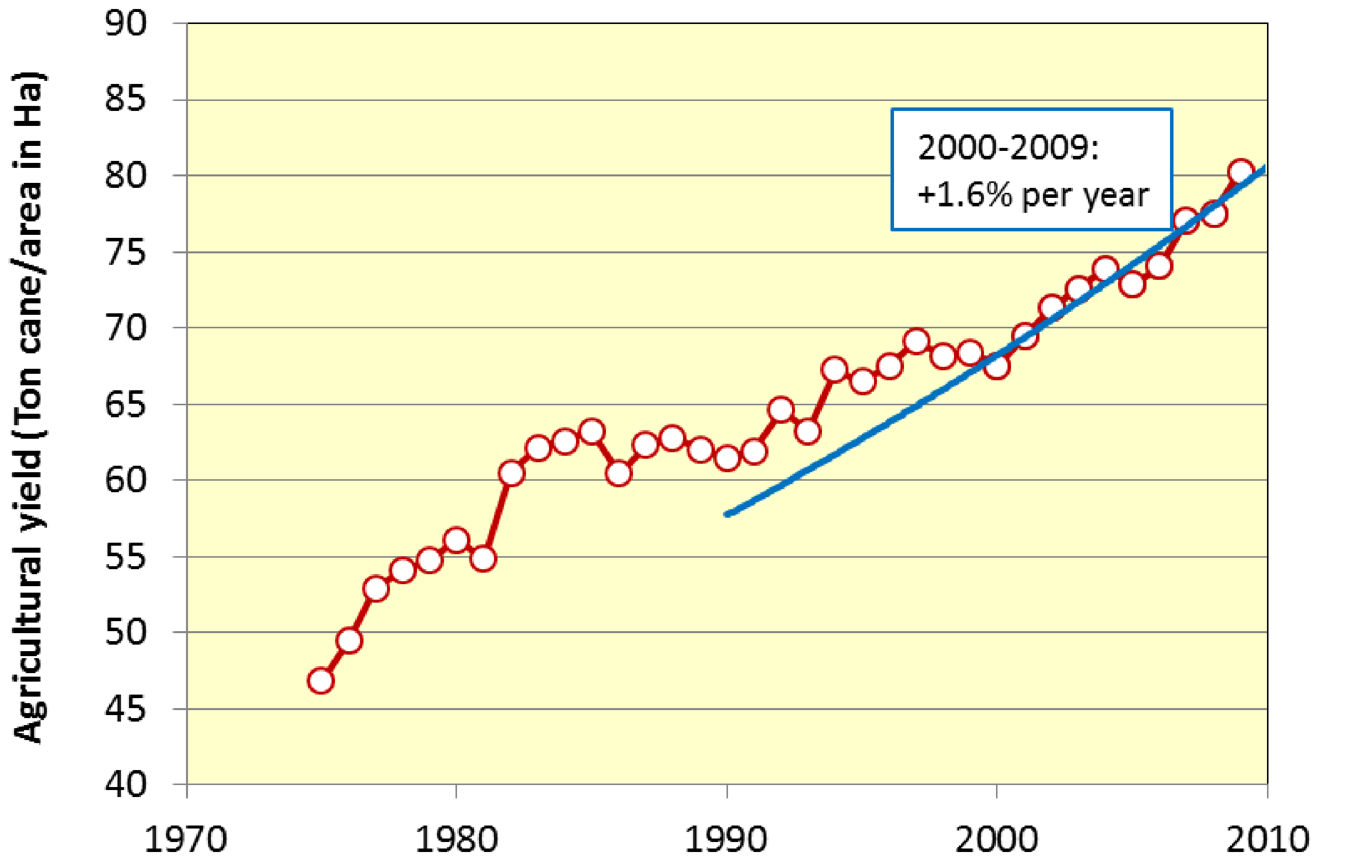
(Waclawovski et al, “Sugarcane for bioenergy production: assessment of yield and regulation of sucrose content “, PBJ 2009)

Productivity growth: 1.5% per year for sugarcane

Feedstock type	Regions	Yield trend (%/yr)	Potential yield increase by 2030 (%)	Improvement routes	Ref.
DEDICATED CROPS					
Wheat	Temperate	0.7	20-50	New energy-oriented varieties	1,10
	Subtropics		30-100	Higher input rates, irrigation	
Maize	N America	0.7	20-35	New varieties, GMOs, higher plantation density, reduced tillage Higher input rates, irrigation	
	Subtropics		20-60		
	Tropics		50		
Soybean	USA	0.7	15-35	Breeding	2,3,10
	Brazil	1.0	20-60		
Oil palm	World	1.0	30	Breeding, mechanization	3
Sugarcane	Brazil	1.5	20-40	Breeding, GMOs, irrigation inputs	2,3,8,10
SR Willow	Temperate	-	50	Breeding, GMOs	3
SR Poplar	Temperate	-	45		
Miscanthus	World	-	100	Breeding for minimal input, improved management	
Switchgrass	Temperate	-	100	Genetic manipulation	
Planted forest	Europe Canada	1.3	20 20	Species choice, breeding, fertilization, shorter rotations, increased rooting depth	4,9 11

(Source: Chum, H., et al., IPCC SRREN 2011)

Sugarcane productivity in Brazil: +1.6% per year since 2000



(Source: Anuário Estatistico de Agroenergia 2010 (MAPA 2011)

New technologies

- Reduce land requirement and/or increase sustainability
  - GMOs
    - Less water, more sugars, more fiber
  - Cellulosic
    - Especially for regions with little or no land available
    - Adding to sugar processing will increase the productivity of sugarcane

Africa, South and Central America

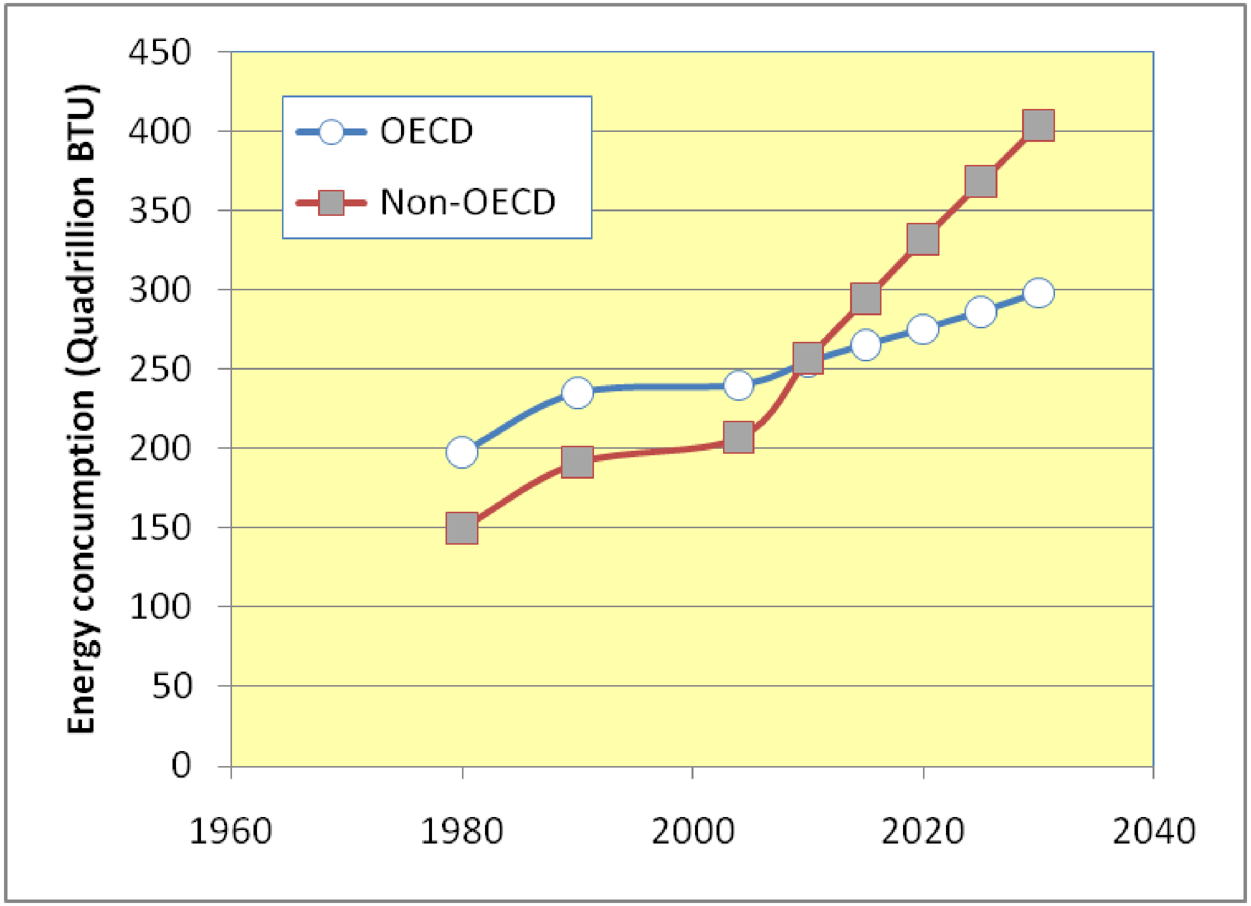
Area available in South & Central America by 2050: 0,25 Gha
Area available in Africa by 2050: 0,18 Gha
(both according to Doornbosch & Steenblik, OECD, 2007)

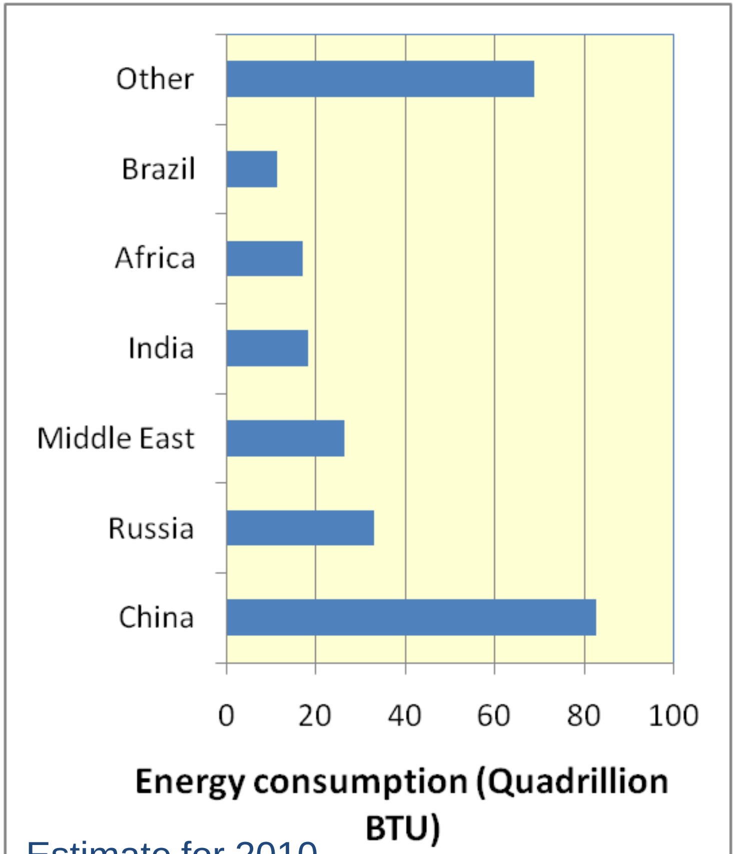
0.43GHa @ 7.7 kL/(Ha.yr) → 3,300 GL /yr (in 2004: 30 GL)

	2004	2050
Gasoline consumption [(1)]	1,200 GL	2,200 GL
Ethanol consumption	30 GL	
Ethanol substituting 10% gasoline		330 GL
Ethanol substituting 100% gasoline		3,300 GL
(1) Source: *National Energy Information Center (NEIC)*		

Potential for substituting for ~100% of the world gasoline demand considering the available area in South and Central America and Africa

Energy consumption OECD and Non-OECD





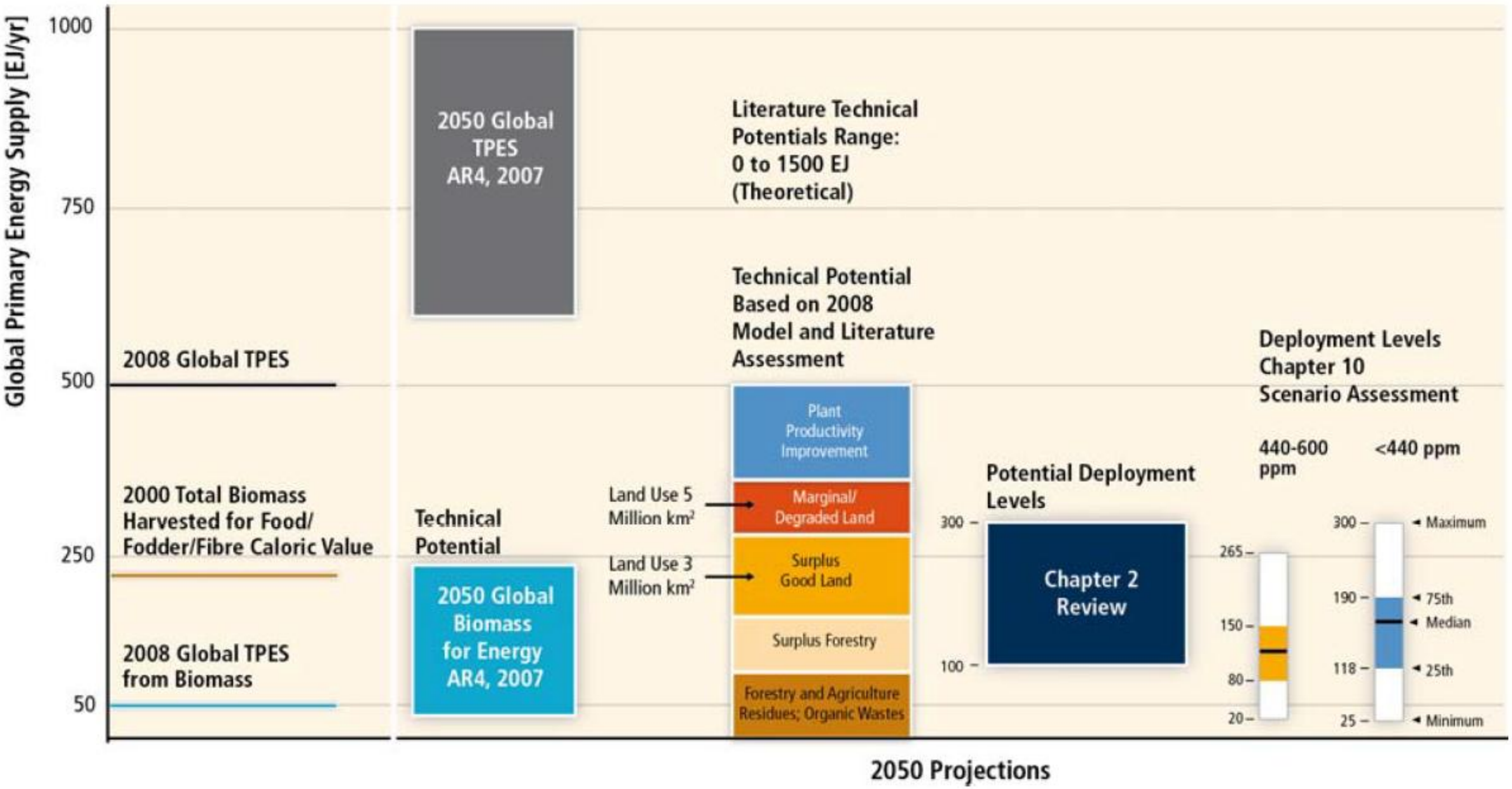
Estimate for 2010

Source: International Energy Outlook 2009

Global Sustainable Bioenergy

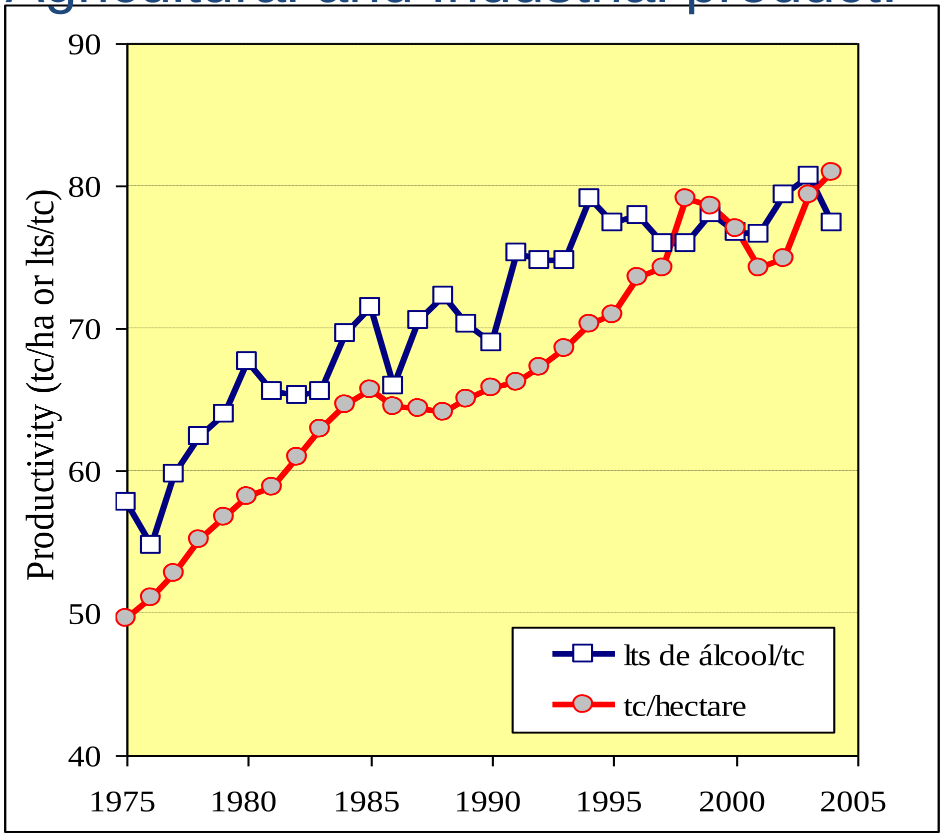
- It is physically possible for bioenergy to sustainably meet a substantial fraction of future demand for energy services (≥ 25% of global mobility or equivalent) while feeding humanity and meeting other needs from managed lands, preserving wildlife habitat, and maintaining environmental quality.
  - We intend to approach this unconstrained by current practices, since a sustainable and secure future cannot be obtained by continuing the practices that have led to the unsustainable and insecure present.

IPCC: WG3 SRREN, 2011: 118-190 EJ from biomass in 2050

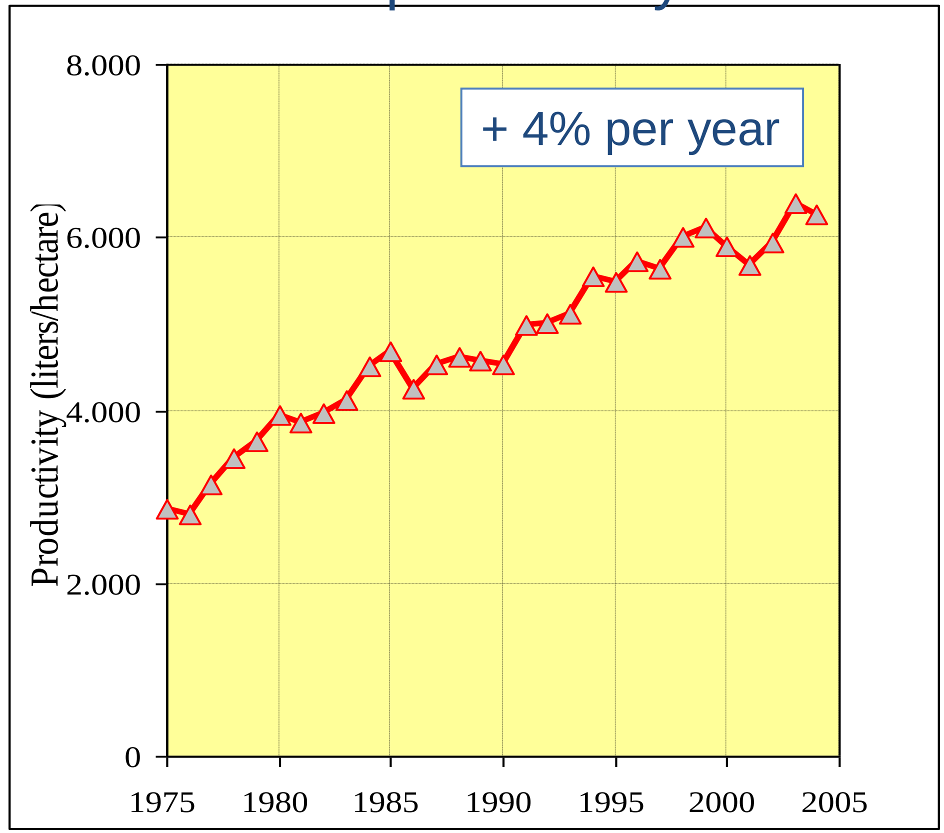


Increase in productivity through R&D

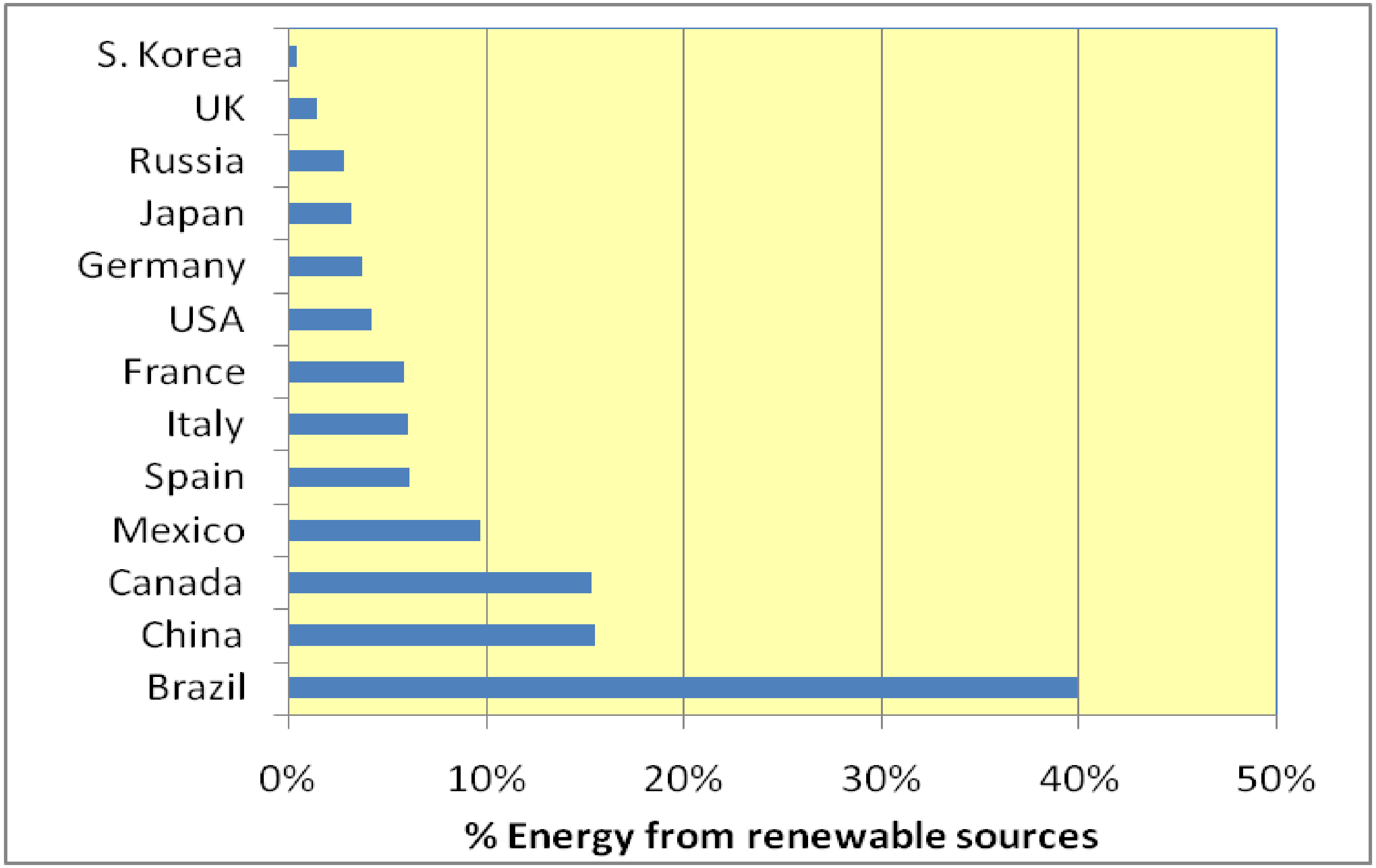
Agricultural and Industrial product.



Total productivity

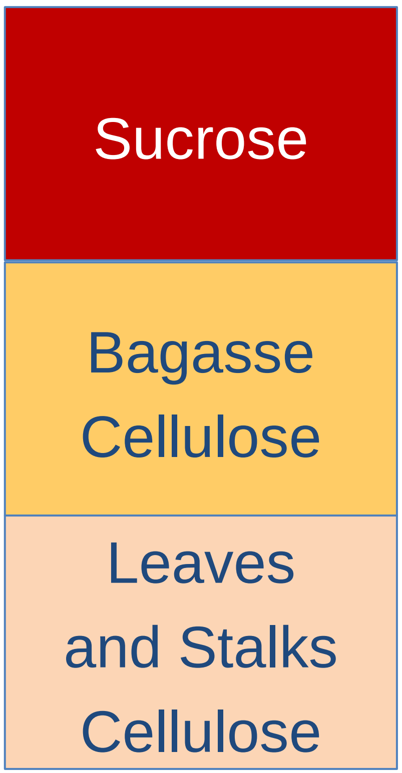


Energy from renewable sources
Some industrialized countries



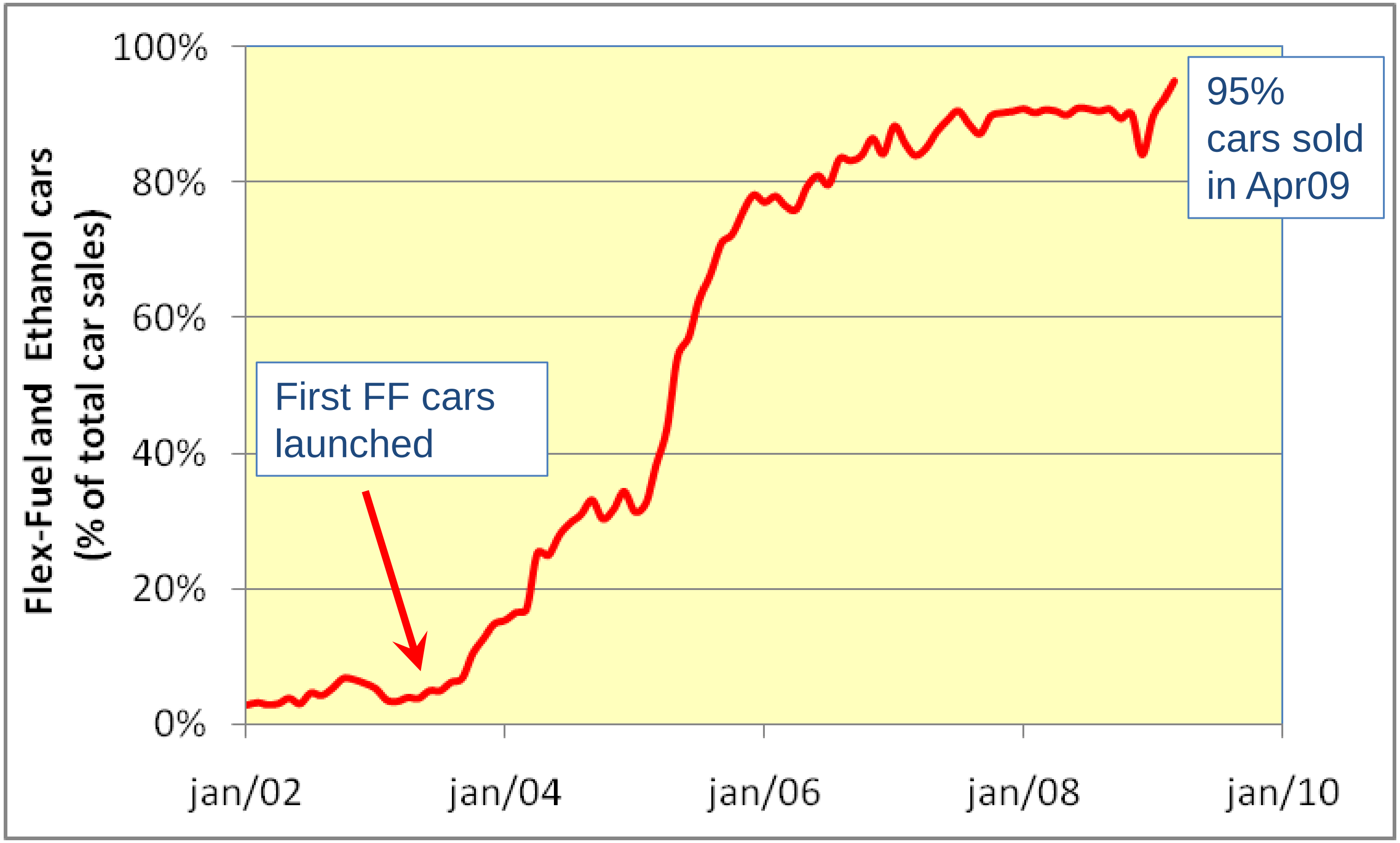
Source: IEA, Renewables Factsheet, 2007

Sugarcane energy content

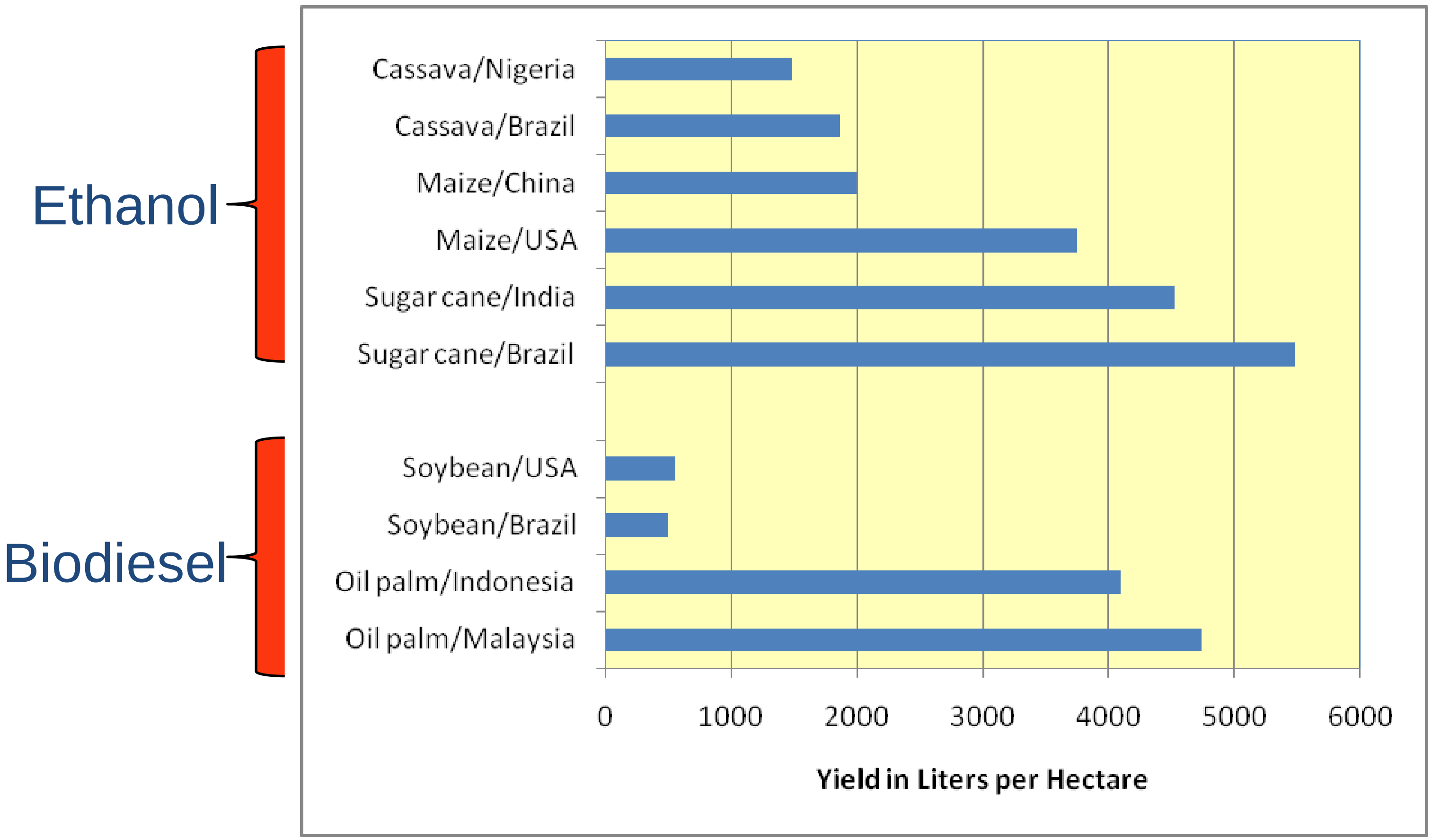


- 1 Ton of Cane = 1,2 Barrels of Oil
- Sucrose → Ethanol
- Bagasse → burnt for heat for the mill and electricity sold to the grid
- Leaves and Stalks → burnt on the field
  - Burning phasing out in SP until 2014/2017

95% of cars sold monthly are Flex-Fuel (FF in Brazil: E10 – E100)

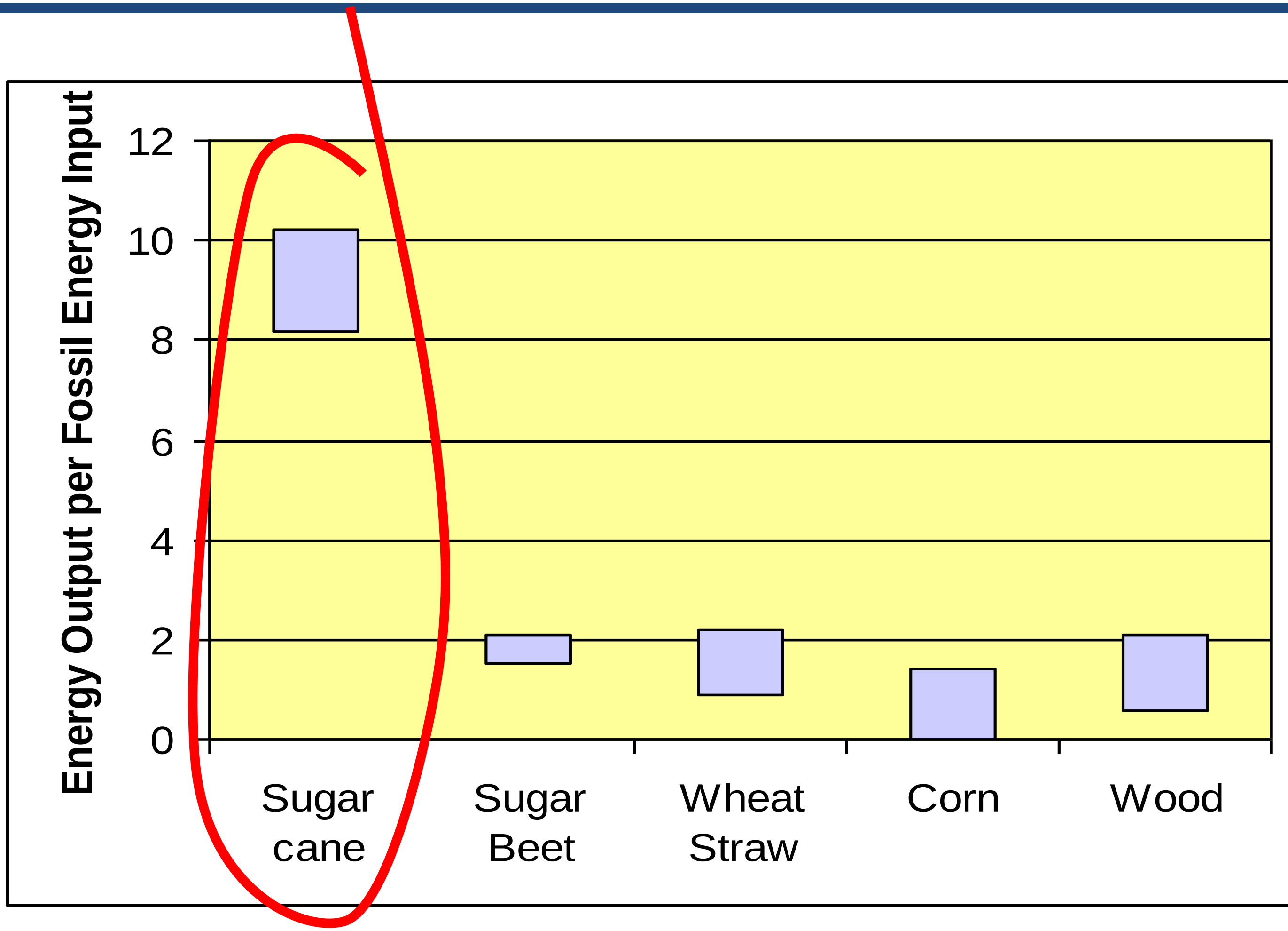


Biofuel yield per hectare

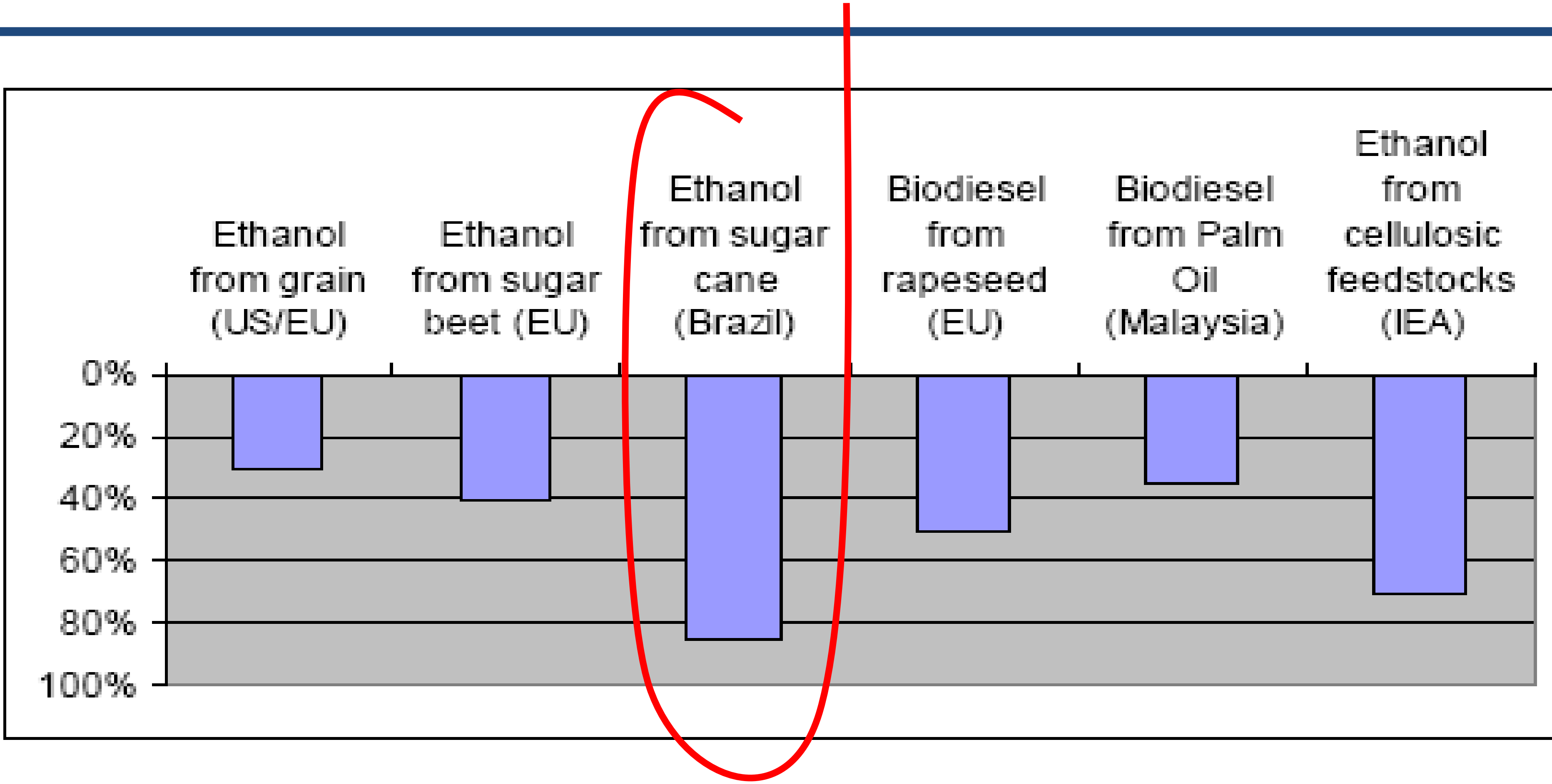


FAO, "The state of agriculture 2008"

Energy balance



GHG reduction



Doornbosch and Steenblik, OECD 2007

GHG and Energy Balance: evolving knowledge

Goldemberg J et al., “Energy Balance for Ethyl Alcohol Production from Crops”, Science 2001 p. 903-906 (1978)

Macedo IC, Seabra JEA, Silva JEAR. Green house gases emissions in the production and use of ethanol from sugarcane in Brazil: The.... Biomass and Bioenergy (2008), doi:10.1016/j.biombioe.2007.12.006

Green house gases emissions in the production and use of ethanol from sugarcane in Brazil: The 2005/2006 averages and a prediction for 2020

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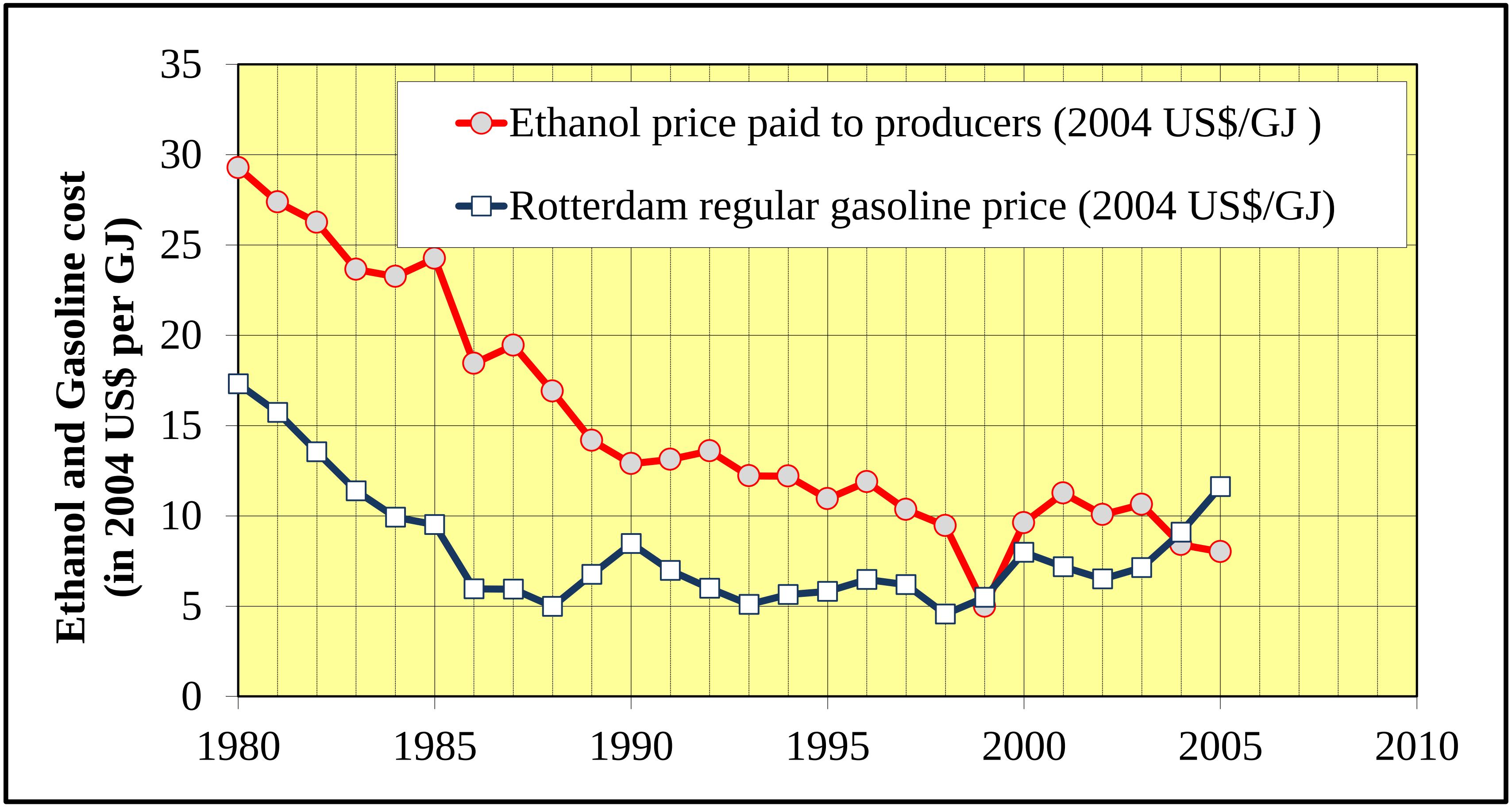
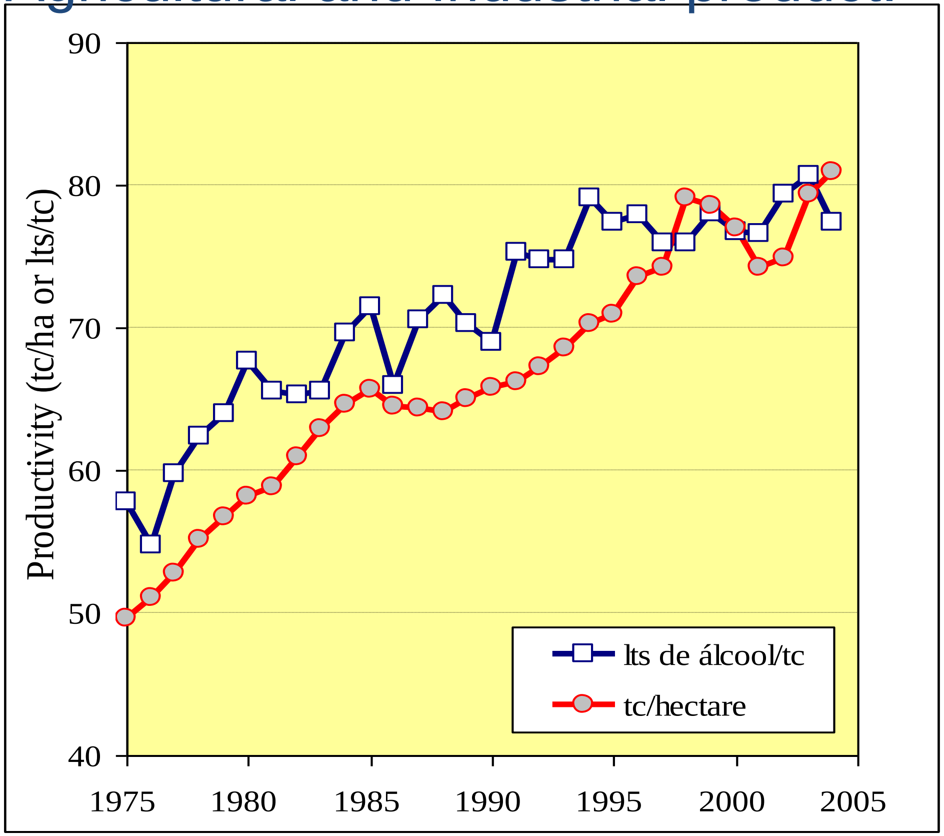
Ethanol costs x Gasoline



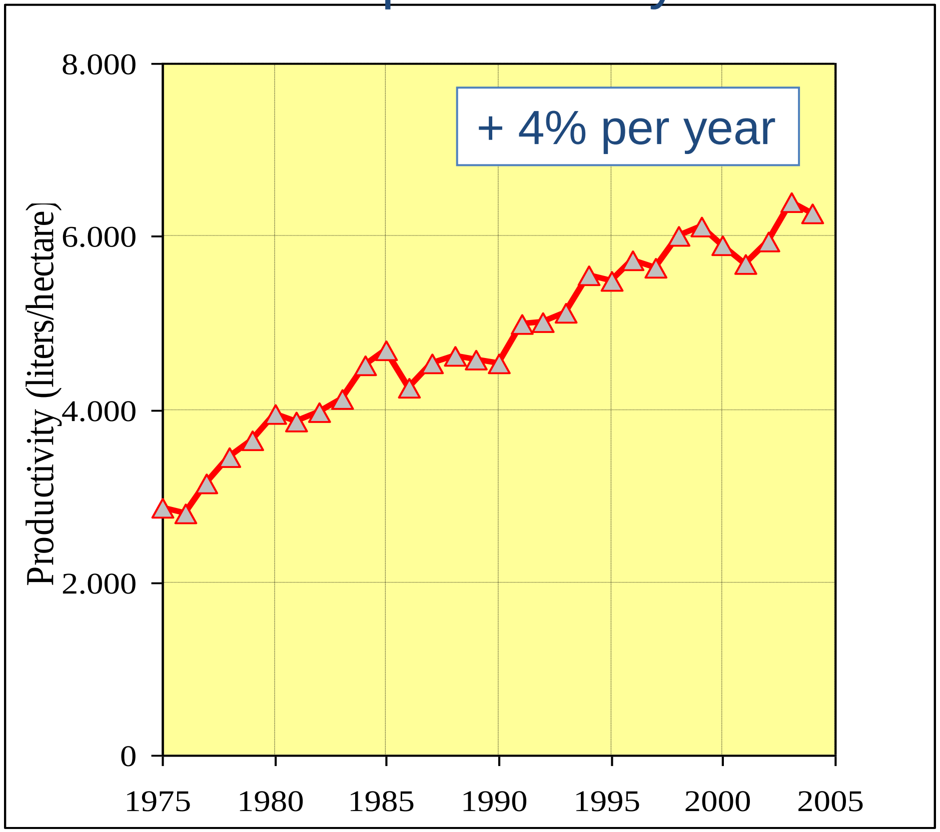
Source: Goldemberg, 2005

Increase in productivity through R&D

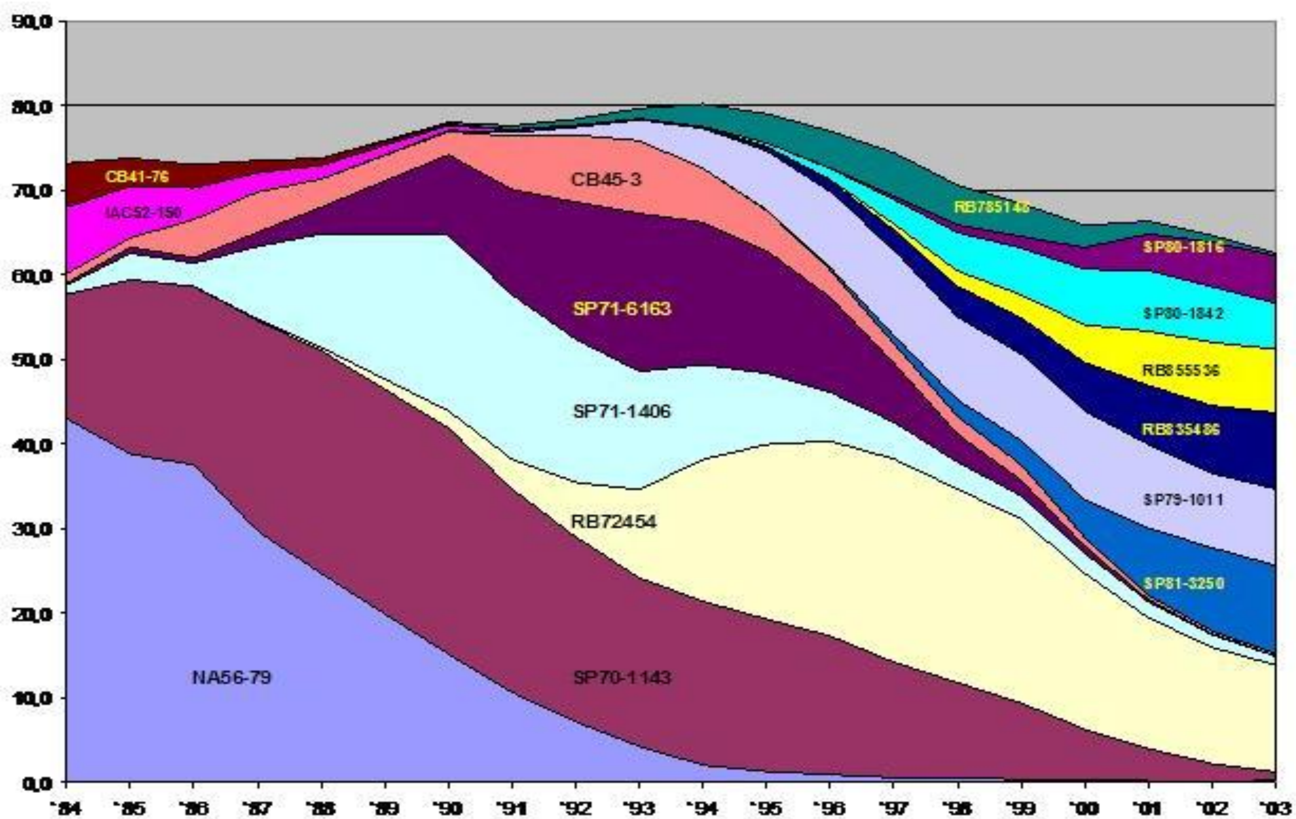
Agricultural and Industrial product.



Total productivity



R&D: Increasing number of Sugarcane varieties used in Brazil

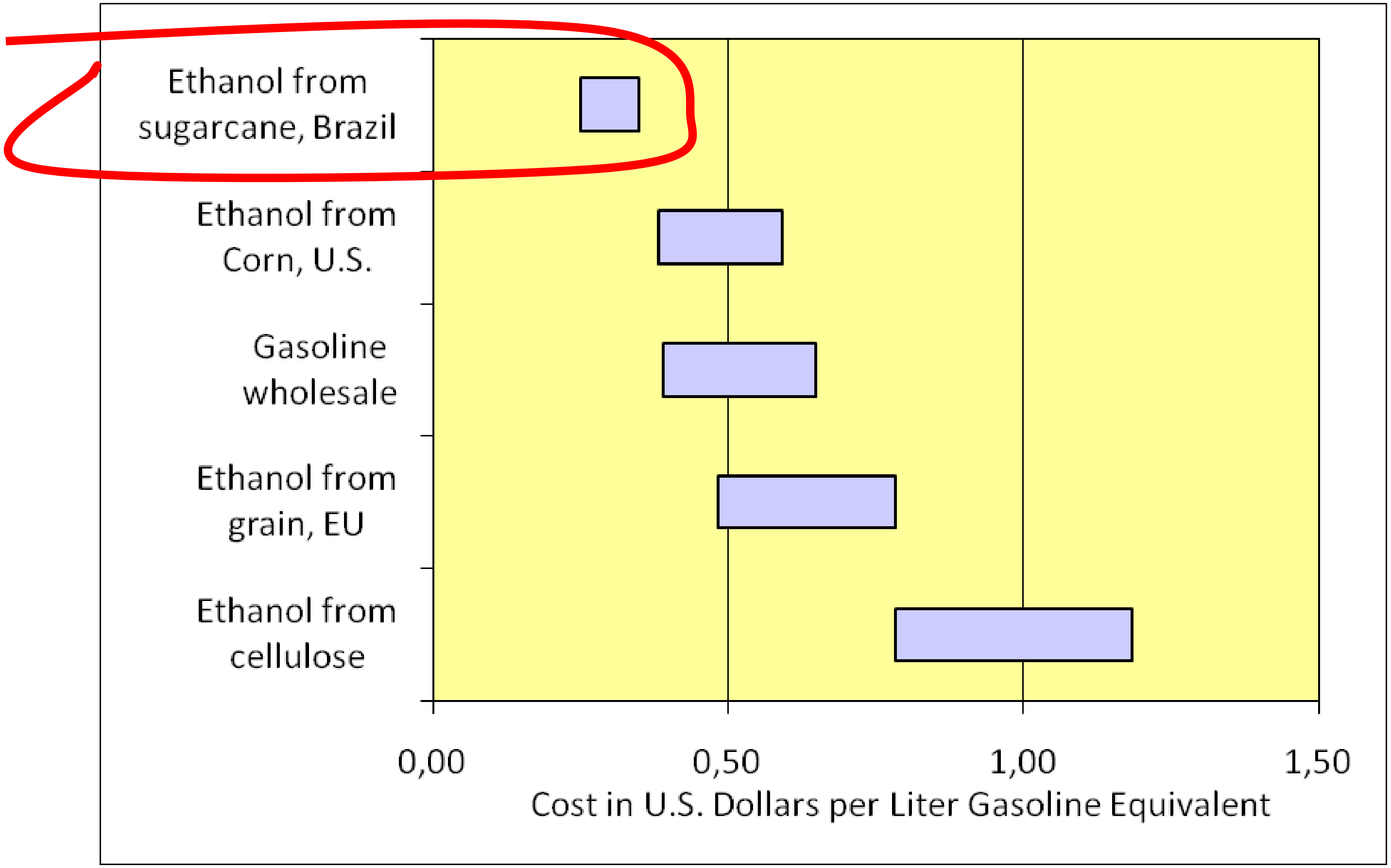


1984 1994 2003

- Developed by 3 research organizations
  - CTC
  - Ridesa
  - IAC
- Plus private companies
  - Alellyx
  - Canaviallis

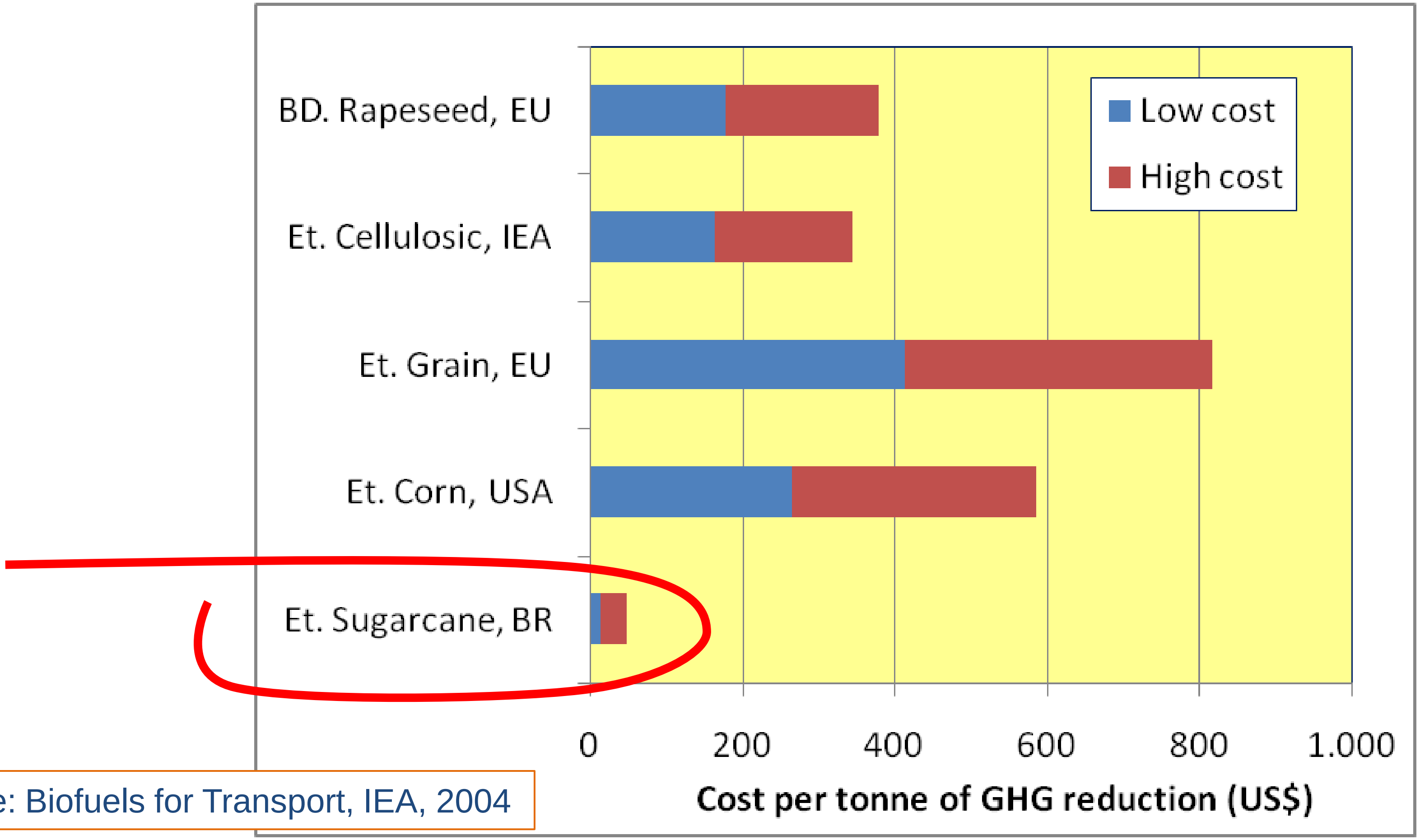
Now Monsanto

Biofuels costs



World Watch 2006, http://www.worldwatch.org/system/files/EBF008_1.pdf

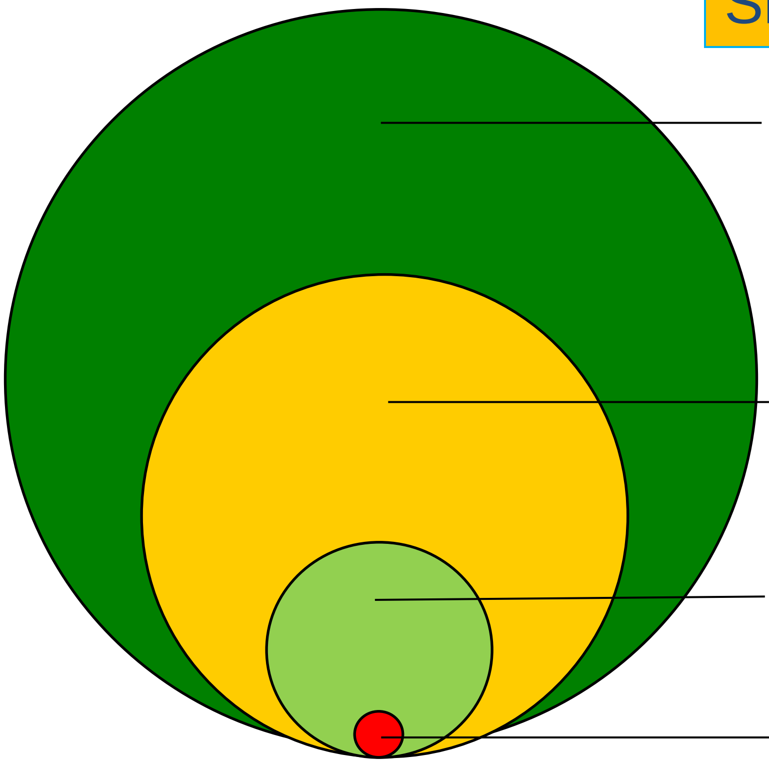
Cost per tonne of reduced GHG



Source: Biofuels for Transport, IEA, 2004

Sugarcane for ethanol uses 0,6% of total area

Small bioenergy footprint



Total country area (851 MHa, 100%)

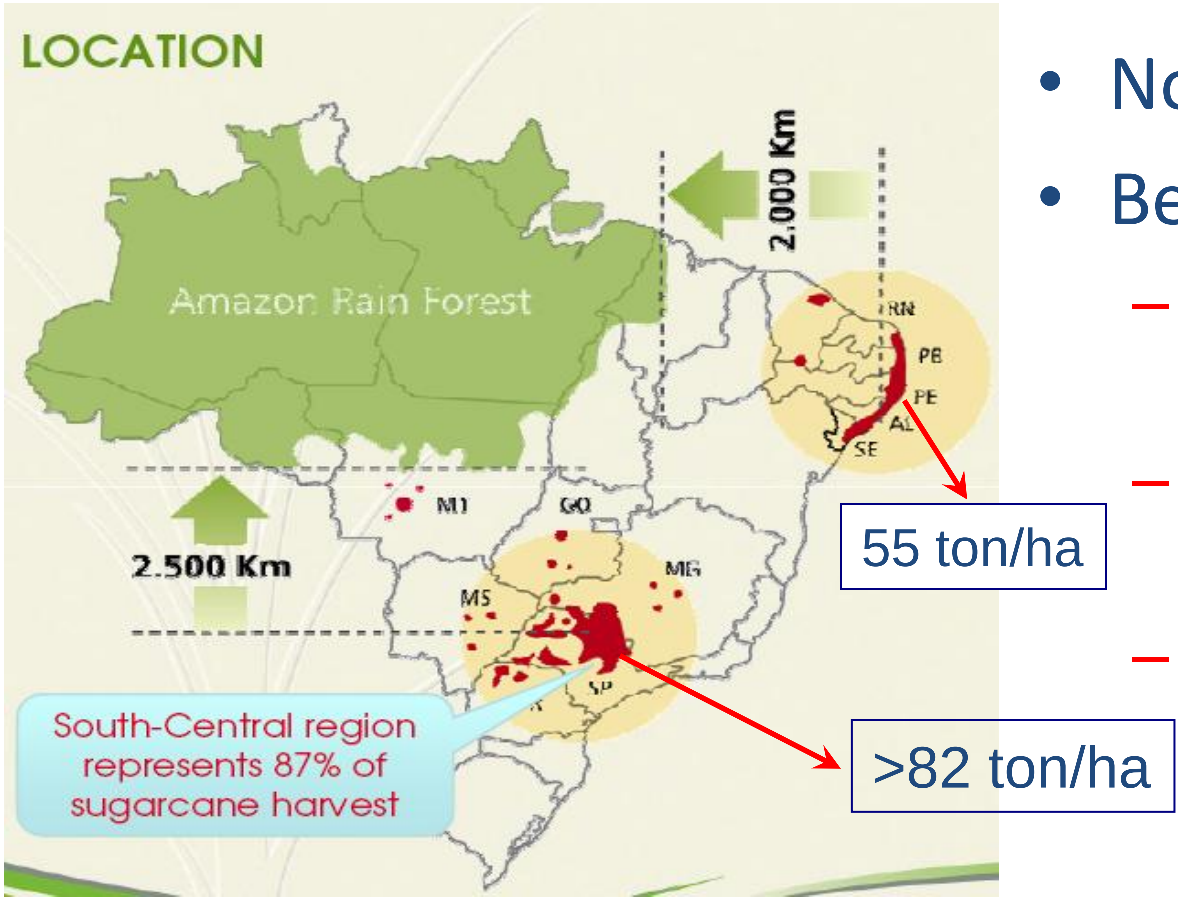
Rural properties area (355 MHa, 42%)

Area used for agriculture (76,7 MHa, 9%)

Area used for sugarcane for ethanol (4,8 MHa, 0,6%)

Source: Horta Nogueira e Seabra (2008) modified for 2008 data

Where does Brazil plant Sugarcane?



- Not in the Amazon
- Best land for cane:
  - Northeast coast
    - Oldest (XVI century)
  - Southeast
    - highest productivity
  - Centralwest
    - main expansion area

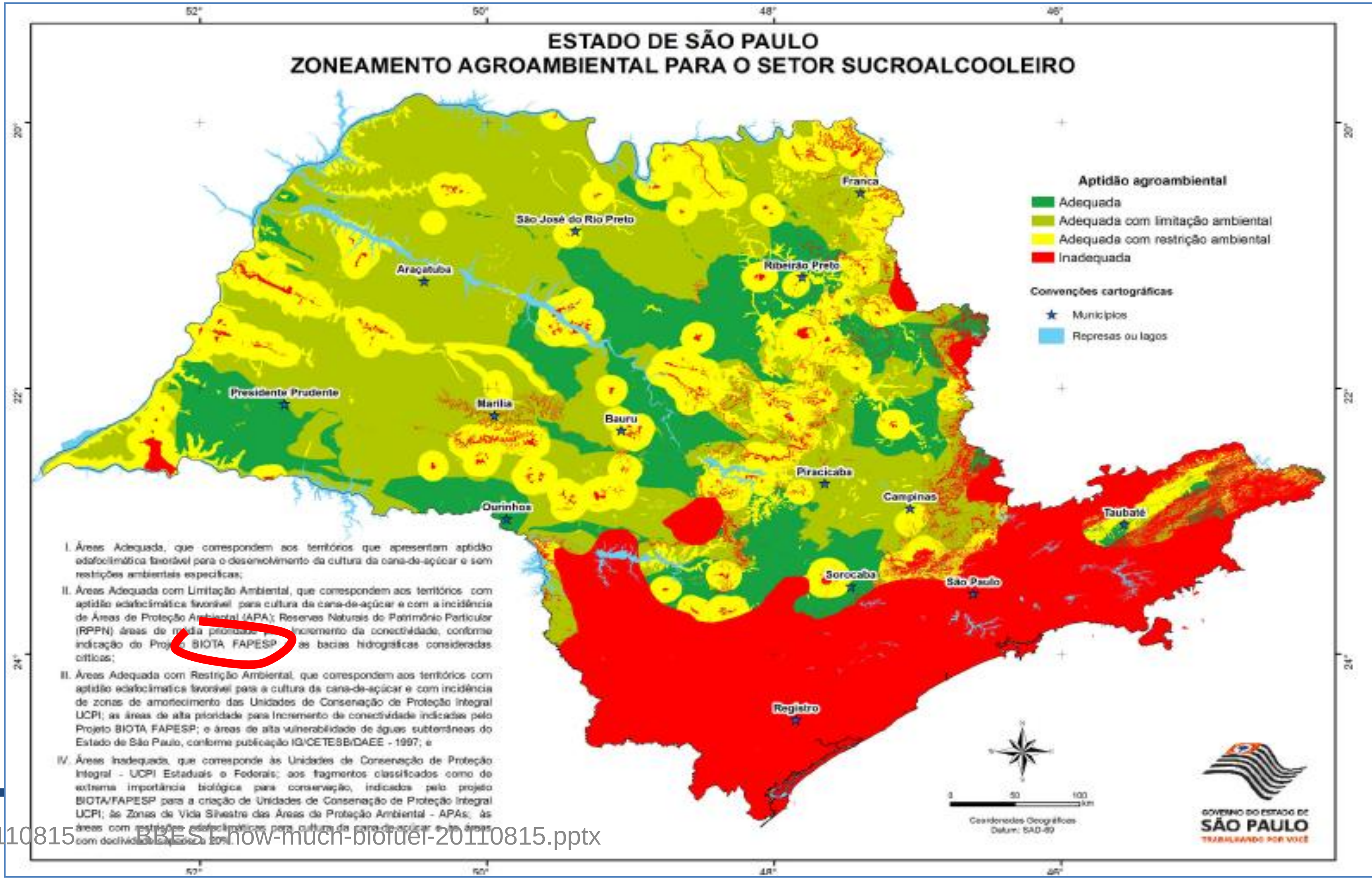
Challenges in Bioenergy in Brasil

- Productivity
  - Biomass production
  - Conversion processes
  - Cellulose uses: electricity x liquid fuel
- Sustainability
  - Emissions (LUC, ILUC, N)
  - Water use
  - The new agriculture of Food and Energy
  - Environmental impacts
  - Social impacts
  - Economics: regulation, standards, certification

Fapesp: São Paulo Research Foundation

- Mission: support research in all fields
- Receives 18,000 proposals per year, all peer reviewed
- Funded by the State of São Paulo with 1% of all state tax revenues
- Started operations in 1962
- Annual budget: US$ 408 M in 2009
  - Fellowships (3,000 SI, 3,000 MS, 3,000 DR, 1,300 PD)
  - Academic R&D
    - Young Investigators
  - University-Industry Joint R&D
  - Small bussiness R&D
    - 1,200 SBE's (three awards per week in 2007)

Science based Sugarcane Agroecological Zoning in São Paulo



Bioenergy: three research initiatives at FAPESP

- Scientific and Technology roadmap
  - Research Project in our Public Policy Program
- BIOEN
  - Research program; 5-10 years
  - Basic research core
  - Conections to application through partnership with companies
- Bioenergy State Research Center
  - Hubs in the three state universities – USP, Unicamp, Unesp
  - Funding: State Government, FAPESP and the Universities

FAPESP's Research Program on Bioenergy (BIOEN): 5 areas

1. Improvements in the feedstock: building a better cane plant <u>for energy</u> - EnergyCane
2. Production of Ethanol and other products: hydrolysis, pyrolisis, gasification, fermentation, distillation
3. New processes in alcohol-chemistry
4. Ethanol based engine and fuel cell developments
5. The Economics of Ethanol, Ethanol production and the environment, Social impacts, the new agriculture of food and energy

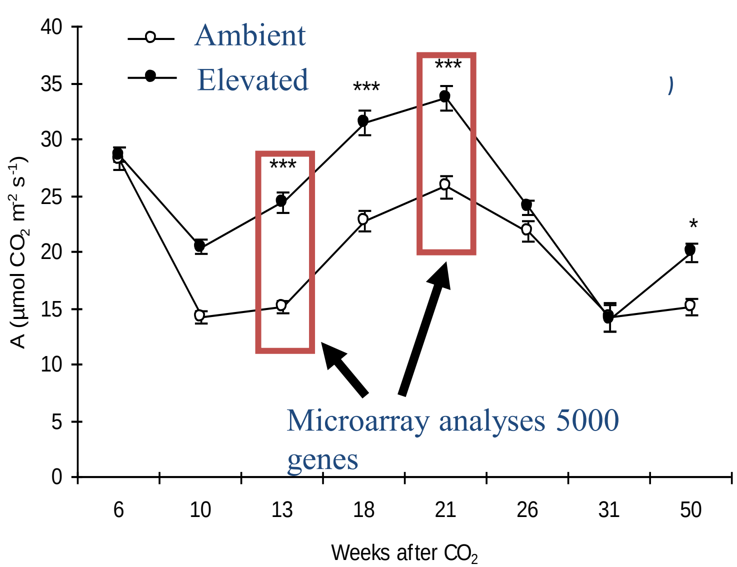
State of São Paulo Bioenergy R&D – BIOEN

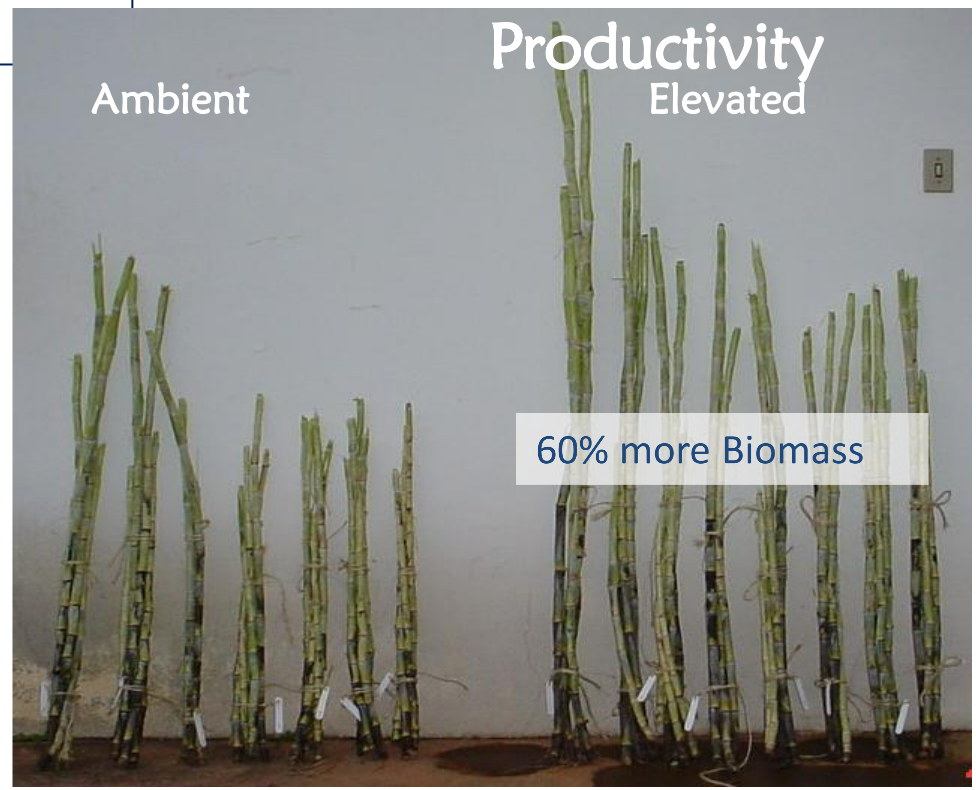
- Academic Basic and Applied Research
  - Advancement of knowledge – US$ 24M (2008) + 2009,..
    - Plus US$ 70 M (10 years) for a Statewide Research Center
  - Young Investigator Awards – US$ 6 M (2008) + 2009..
    - Open to foreign scientists who want to come to Brazil
- Joint industry-university research (5 years)

Company	Subject	Value by industry
Oxiteno	Lignocellulosic materials	US$ 3,000,000
Braskem	Alcohol-chemistry	US$ 25,000,000
Dedini	Processes	US$ 50,000,000

Sugarcane in increased CO_2

Buckeridge M. Et al. Plant Cell and Environment, vol.31, p. 1116 (2008)





Sucrose related genes

BMC Genomics

BioMed Central

This Provisional PDF corresponds to the article as it appeared upon acceptance. Fully formatted PDF and full text (HTML) versions will be made available soon.

Sugarcane genes associated with sucrose content

BMC Genomics 2009, 10:120 doi:10.1186/1471-2164-10-120

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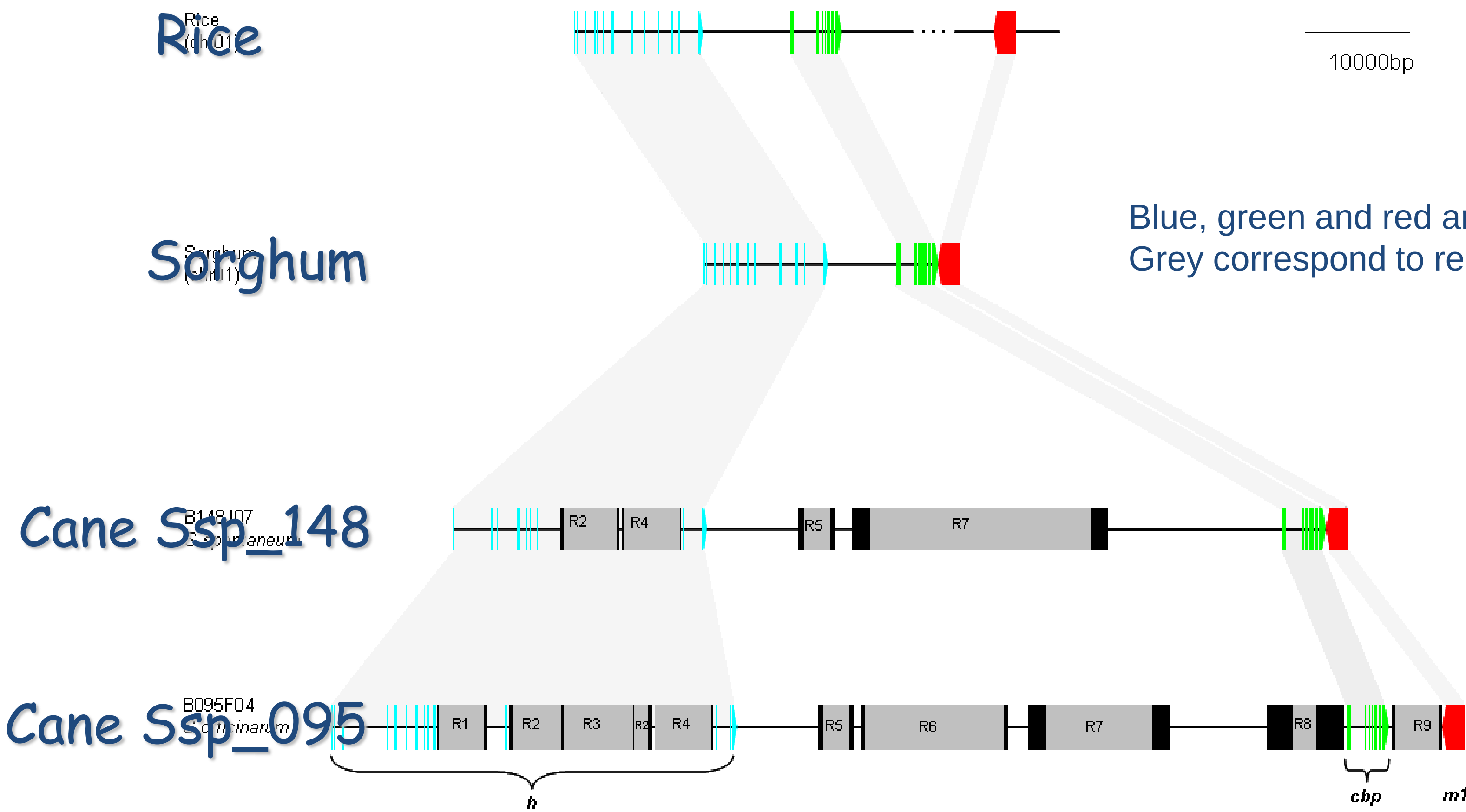
Syntenic regions: rice, sorghum, two cane alleles



Blue, green and red are genes
Grey correspond to repetitive regions

M.Anne van Sluys et al., in preparation

Conclusion

- Brazil created a large and successful experiment on planting fuel since 1975
- Sugarcane has special characteristics
  - Productivity
  - GHG reduction
  - Favorable energy balance
- Brazilian strategy counts on many other countries producing Ethanol from various sources
  - Technology transfer
  - Cooperative R&D
- R&D strategy: more with less (less area, water, energy,...)
- Most probable producers: Latin America and Africa
  - Access to energy for developing countries

Main Research Initiatives in Cane and Ethanol in Brazil

- CTC: private center to assist industry
- Ridesa: public/private network for cane breeding
- IAC: state institute on agronomic research
- Universities: USP, Unicamp, Unesp, Ufscar, UFV
- INMETRO: Certification
- CTBE: Bioethanol Research Center
- EMBRAPA Agroenergy Center
- Fapesp Initiatives on Bioenergy

SUCEST: Gene Discovery and Functional Genomics

- Genes associated to traits of interest
- In association with planters R&D center
  - Sugarcane Transcriptome Project (University of São Paulo, USP)
    - Over 1,000 trait genes (sucrose, herbivory, drought, nutritional responses) identified through genomics tools applied to the study of the Brazilian germplasm (Pat pending USPTO11/716,262)
  - Sugarcane Molecular Marker Development Project (University of Campinas, UNICAMP)
    - A functional map and markers associated to sucrose content developed for breeding populations

R&D challenges for Brazil's strategy - I

- Molecular Biology in sugarcane improvement
  - Whole Genome Shotgun
  - Networks, signals, transcriptome
- Targets
  - 90 ton/Ha → 200 ton/Ha
  - Sucrosis content; Water stress; Herbivory

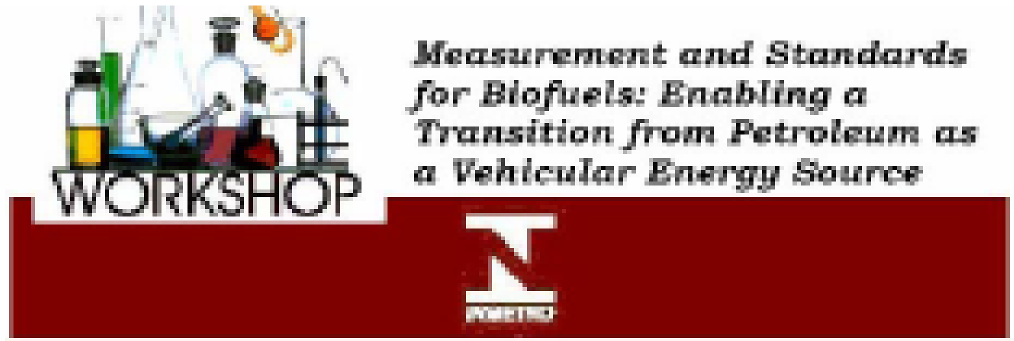
R&D challenges for Brazil's strategy - II

- Cellulosic Ethanol
  - Cell wall modification
  - Characterization and development of physical, chemical pretreatment of bagasse for ligninocellulose hydrolysis
  - Development of acid catalyzed and biocatalyzed saccharification
  - Development of high performance cellulases and hydrolases
  - Removal of fermentation inhibitors
  - Development of microorganism strains
  - Effluent disposal and environmental friendly accepted processes

Mechanical harvest avoids burning

Standards

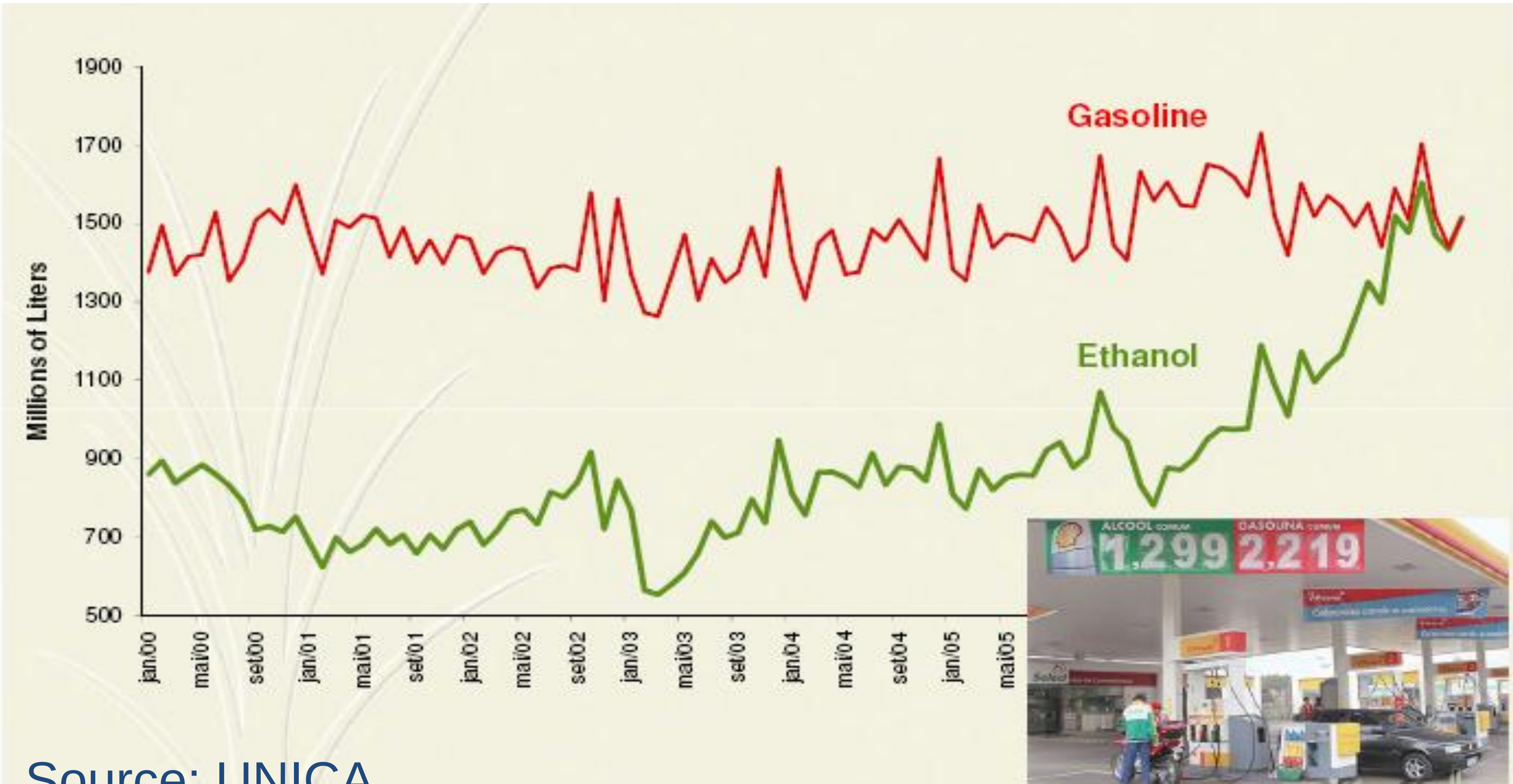

Symposium on Biofuels
Measurements and Standards to Facilitate the Transition to a Global Commodity
Hosted by:
the US National Institute of Standards and Technology (NIST)
and
Brazil's National Institute of Metrology, Standardization and Industrial Quality (INMETRO)
In conjunction with the
11th Annual Green Chemistry & Engineering Conference:
From Small Steps to Giant Leaps – Breakthrough Innovations for Sustainability
Capital Hilton in Washington, DC
June 26-29, 2007
GREEN CHEMISTRY


WORKSHOP
Measurement and Standards for Biofuels: Enabling a Transition from Petroleum as a Vehicular Energy Source

High quality measurement standards

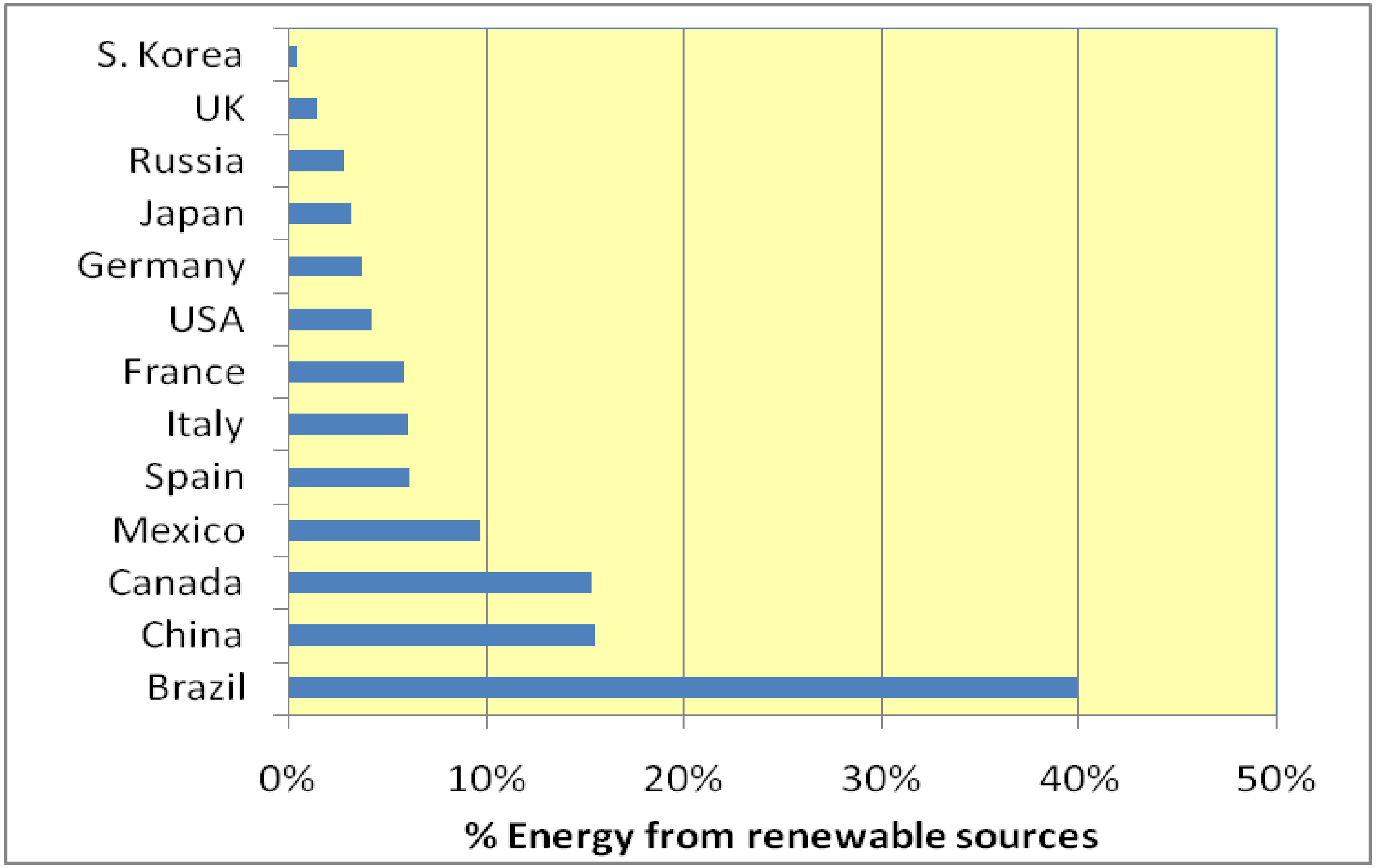
- Inmetro (Brazil) and NIST (EUA) exchange CRMs – Ethanol (Inmetro); Soy Biodiesel (NIST) for validation
- Project BIOREMA – CRMs with UE

Brazil: Gasoline and Ethanol consumption



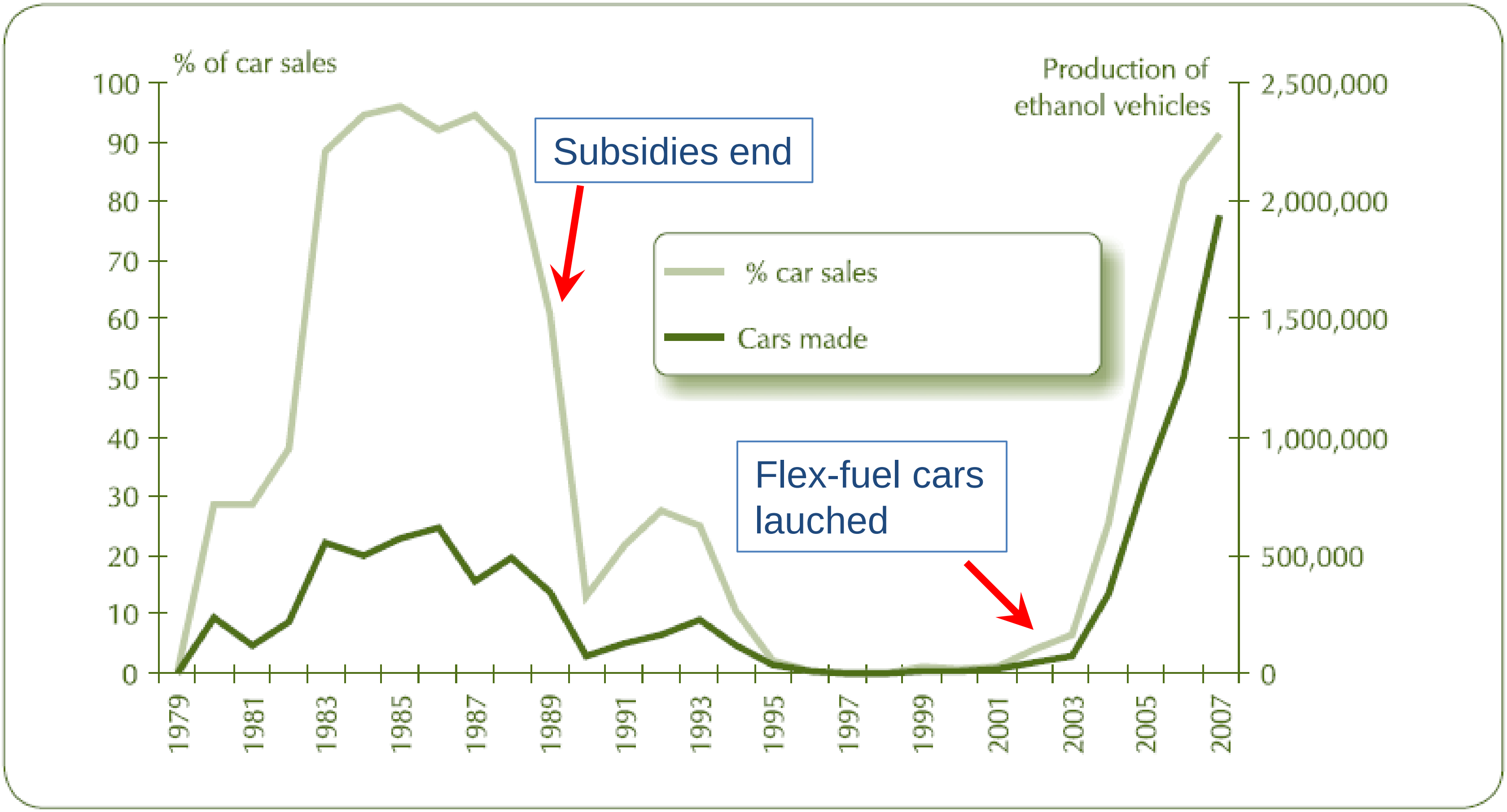
Source: UNICA

Energy from renewable sources Some industrialized countries

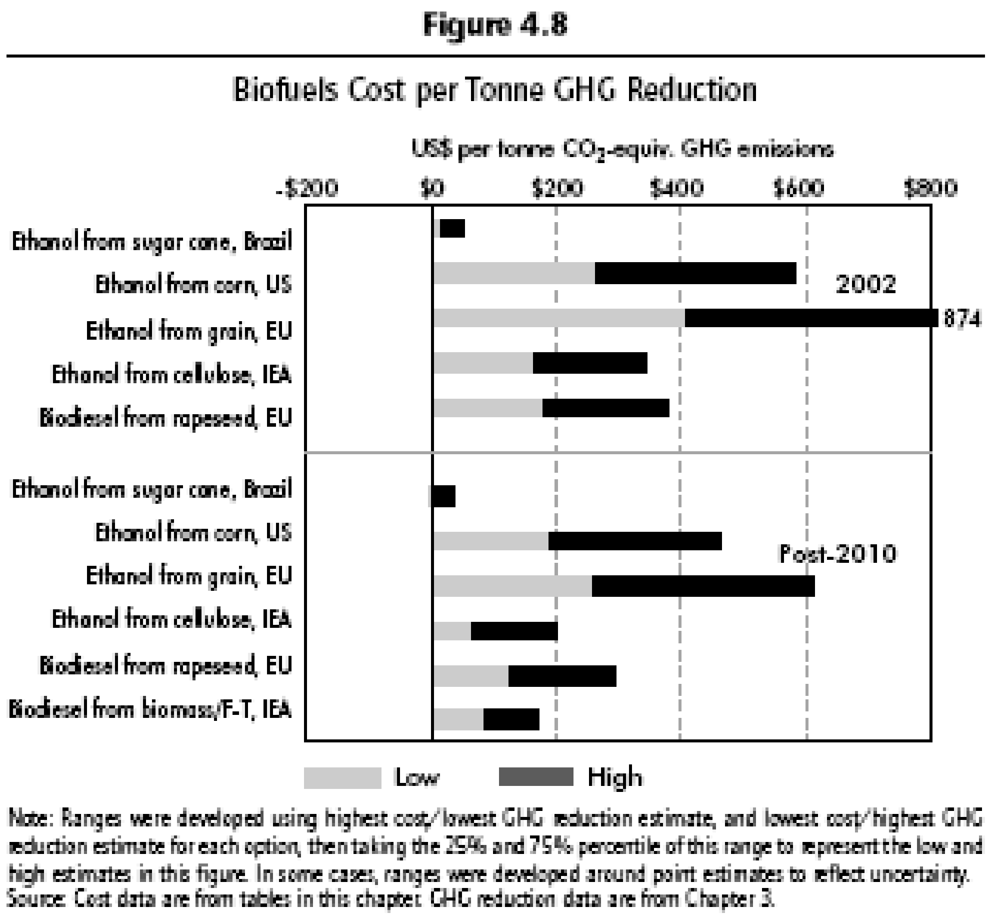


Source: IEA, Renewables Factsheet, 2007

Production and Sales of Ethanol based Automobiles



Cost of biofuels per tonne of GHG reduction



FAPESP (The São Paulo Research Foundation): SUCEST Program, 1999

- Started 1999
- Molecular Biology tools for improving sugarcane
- Science and Technology of sugarcane
  - Articles, thesis and patents
  - Human resources

SUCEST Project
FAPESP, 1999 - 2004

Genome Research

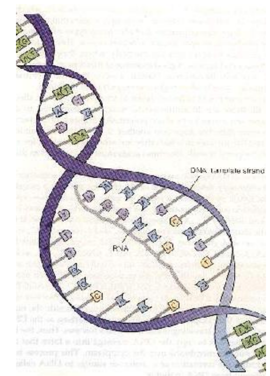
13:2725–2735 ©2003 by Cold Spring Harbor Laboratory Press ISSN 1088-9051/03 $5.00; www.genome.org

Analysis and Functional Annotation of an Expressed Sequence Tag Collection for Tropical Crop Sugarcane

André L. Vettore,[1,24] Felipe R. da Silva,[1,25] Edson L. Kemper,[1,26] Glaucia M. Souza,[3] Aline M. da Silva,[3] Maria Inês T. Ferro,[6] Flavio Henrique-Silva,[8] Éder A. Giglioti,[9] Manoel V.F. Lemos,[7] Luiz L. Coutinho,[10] Marina P. Nobrega,[11] Helaine Carrer,[10] Suzelei C. França,[12] Maurício Bacci Jr.,[13] Maria Helena S. Goldman,[14] Suely L. Gomes,[3] Luiz R. Nunes,[15] Luis E.A. Camargo,[10] Walter J. Siqueira,[16] Marie-Anne Van Sluys,[4] Otavio H. Thiemann,[17] Eiko E. Kuramae,[18] Roberto V. Santelli,[3] Celso L. Marino,[19] Maria L.P.N. Targon,[20] Jesus A. Ferro,[6,27] Henrique C.S. Silveira,[8] Danyelle C. Marini,[9] Eliana G.M. Lemos,[6] Claudia B. Monteiro-Vitorello,[10] José H.M. Tambor,[11] Dirce M. Carraro,[10,24] Patrícia G. Roberto,[12] Vanderlei G. Martins,[21] Gustavo H. Goldman,[22] Regina C. de Oliveira,[15] Daniela Truffi,[10] Carlos A. Colombo,[16] Magdalena Rossi,[4] Paula G. de Araujo,[4] Susana A. Sculaccio,[17] Aline Angella,[18] Marleide M.A. Lima,[18] Vicente E. de Rosa Jr.,[18] Fábio Siviero,[3] Virginia E. Coscrato,[19] Marcos A. Machado,[20] Laurent Grivet,[23] Sonia M.Z. Di Mauro,[6] Francisco G. Nobrega,[11] Carlos F.M. Menck,[5] Marilia D.V. Braga,[2,28] Guilherme P. Telles,[2] Frank A.A. Cara,[2] Guilherme Pedrosa,[2] João Meidanis,[2] and Paulo Arruda[1,27,29]

50 labs

200 researchers



238000 ESTs

43000 Transcripts

BMC Genomics BioMed Central

Research article **Open Access**

Signal transduction-related responses to phytohormones and environmental challenges in sugarcane

Flávia R Rocha[1], Flávia S Papini-Terzi[1], Milton Y Nishiyama Jr[1], Ricardo ZN Vêncio[2], Renato Vicentini[3], Rodrigo DC Duarte[3], Vicente E de Rosa Jr[3], Fabiano Vinagre[4], Carla Barsalobres[5], Ane H Medeiros[5], Fabiana A Rodrigues[7], Eugênio C Ulian[6], Sônia M Zingaretti[7], João A Galbiatti[7], Raul S Almeida[8], Antonio VO Figueira[8], Adriana S Hemerly[4], Marcio C Silva-Filho[5], Marcelo Menossi[3] and Gláucia M Souza*[1]

Published: 13 March 2007

BMC Genomics 2007, **8**:71 doi:10.1186/1471-2164-8-71

Received: 18 August 2006
Accepted: 13 March 2007

Int J Plant Genomics. 2008; 2008: 458732. PMCID: PMC2216073
Published online 2007 December 16. doi: 10.1155/2008/458732.

Sugarcane Functional Genomics: Gene Discovery for Agronomic Trait Development

M. Menossi,[1] M. C. Silva-Filho,[2] M. Vincentz,[1] M.-A. Van-Sluys,[3] and G. M. Souza[4*]

SUCEST-FUN Project

Sucrose

Drought

Biomass

ABA

Lignin

Herbivory

Fiber

Phosphate

CO_2

MeJA

Sugars

Endophytes

Papini-Terzi, F.S. *et al.* **Proc. Int. Soc. Sugar Cane Technol., Vol. 26, 2007**

THE SUCEST-FUN PROJECT: IDENTIFYING GENES THAT REGULATE SUCROSE CONTENT IN SUGARCANE PLANTS

By

F.S. PAPINI-TERZI[1*], J.M. FELIX[2*], F.R. ROCHA[1], A.J. WACLAWOVSKY[1], E.C. ULIAN[3], S. M. CHABREGAS[3], M.C. FALCO[3], M.Y. NISHIYAMA-JR[1], R.Z.N. VÊNCIO[4], R. VICENTINI[2], M. MENOSSI[2] and G.M. SOUZA[1]

DNA RESEARCH 12, 27–38 (2005)

Transcription Profiling of Signal Transduction-Related Genes in Sugarcane Tissues

Flávia STAL PAPINI-TERZI,[1,†] Flávia RISO ROCHA,[1,†] Ricardo ZORZETTO NICOLIELLO VÊNCIO,[2] Kátia Cristina OLIVEIRA,[1] Juliana de Maria FELIX,[3,4] Renato VICENTINI,[4] Cristiane de SOUZA ROCHA,[4] Ana Carolina QUIRINO SIMÕES,[1] Eugênio César ULIAN,[5] Sônia Marli ZINGARETTI DI MAURO,[6] Aline Maria DA SILVA,[1] Carlos Alberto de BRAGANÇA PEREIRA,[2] Marcelo MENOSSI,[3,4] and Gláucia MENDES SOUZA[1,*]

Maps and Markers

Mol Breeding (2007) 20:189–208
DOI 10.1007/s11032-007-9082-1

Functional integrated genetic linkage map based on EST-markers for a sugarcane (*Saccharum* spp.) commercial cross

Karine M. Oliveira · Luciana R. Pinto · Thiago G. Marconi · Gabriel R. A. Margarido · Maria Marta Pastina · Laura Helena M. Teixeira · Antônio V. Figueira · Eugênio César Ulian · Antônio Augusto F. Garcia · Anete Pereira Souza

Theor Appl Genet (2006) 112: 298–314
DOI 10.1007/s00122-005-0129-6

ORIGINAL PAPER

A. A. F. Garcia · E. A. Kido · A. N. Meza
H. M. B. Souza · L. R. Pinto · M. M. Pastina
C. S. Leite · J. A. G. da Silva · E. C. Ulian
A. Figueira · A. P. Souza

Development of an integrated genetic map of a sugarcane (*Saccharum* spp.) commercial cross, based on a maximum-likelihood approach for estimation of linkage and linkage phases

Hereditas 144: 78–79 (2007)

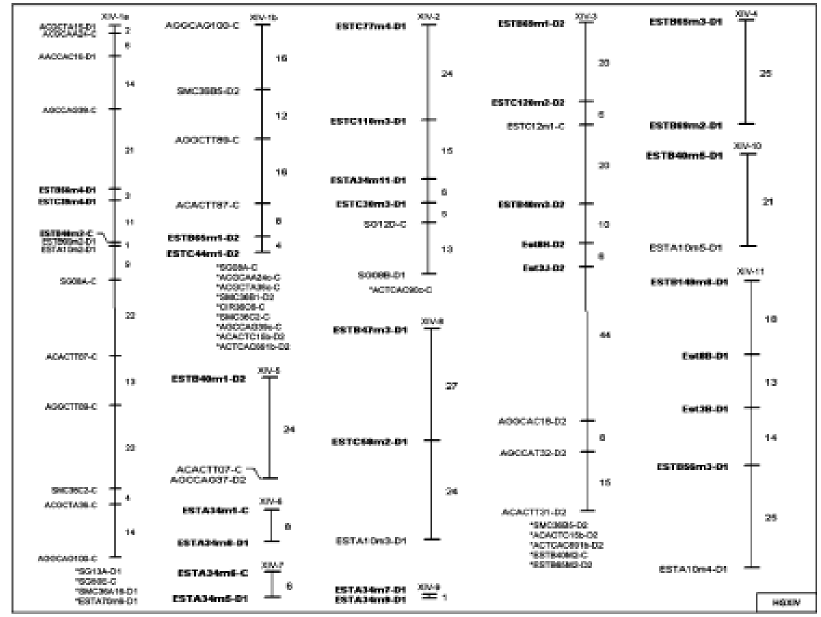
OneMap: software for genetic mapping in outcrossing species

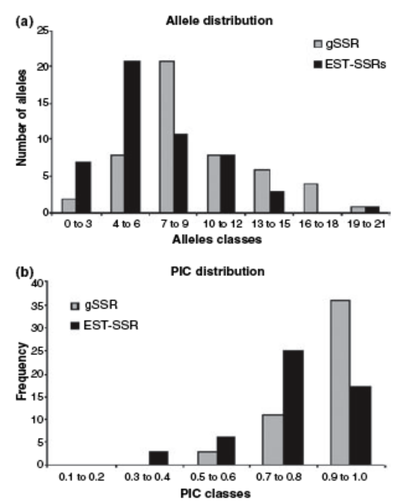
G. R. A. MARGARIDO[1], A. P. SOUZA[2] and A. A. F. GARCIA[1]
[1]*Department of Genetics, Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo (USP), Piracicaba, São Paulo, Brazil*
[2]*Centro de Biologia Molecular e Engenharia Genética (CBMEG), Universidade Estadual de Campinas (UNICAMP), Campinas, São Paulo, Brazil*

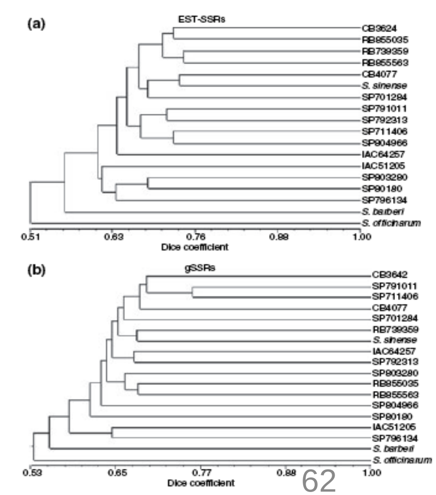
Plant Breeding 125, 378—384 (2006)

Characterization of novel sugarcane expressed sequence tag microsatellites and comparison with genomic SSRs

L. R. Pinto[1], K. M. Oliveira[2], T. Marconi[2], A. A. F. Garcia[3], E. C. Ulian[4] and A. P. de Souza[2]





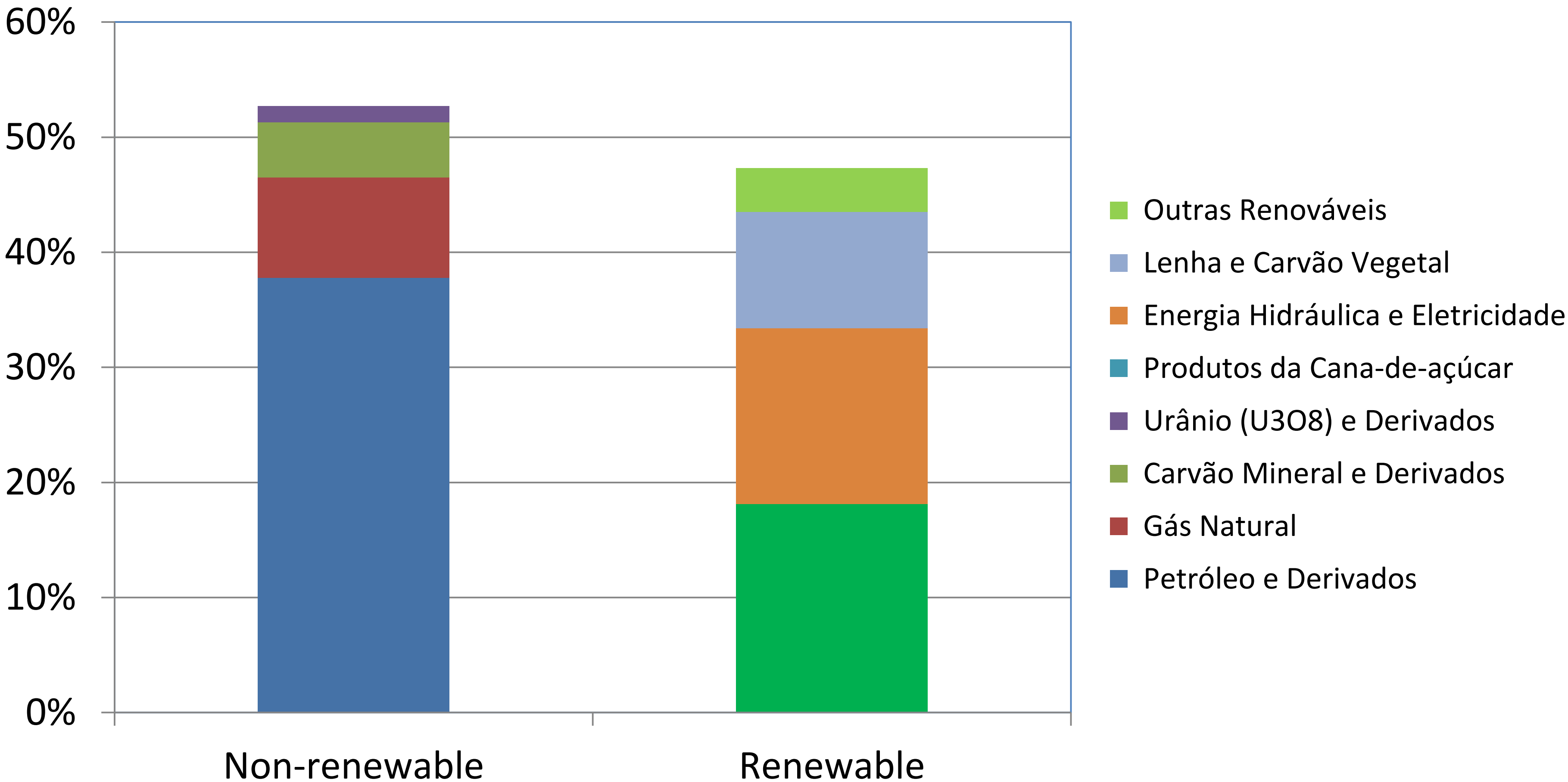


R&D for improving the sugarcane plant

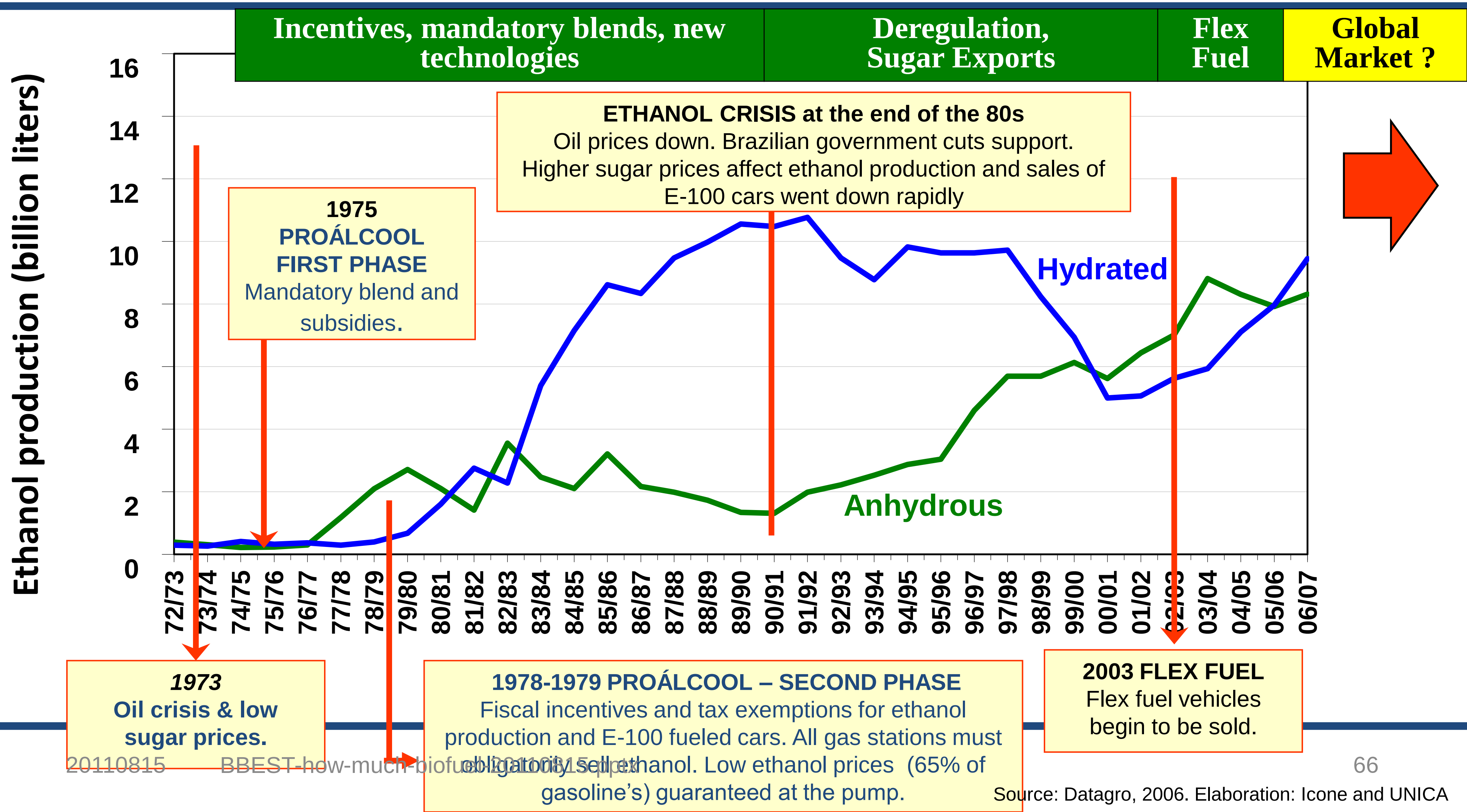
- Traditional genetics and processes
  - 1.3 x in liters/ton
  - 1.6 x in ton/ha
  - Total productivity gain of 2.2 x in 30 years
    - Saved area: 4 Mha (4 x Brazil's area for oranges)
- Next: Genomics based plant improvement
  - Functional genomics
  - Target: full sugarcane genome

Biotechnology + Breeding knowledge

- Target genes which migh help in
  - Increasing yield, and
  - Expansion to pasture land (subject to extended drought season)
  - Easing the need for expansion of planted area
- The SUCEST-FUN Database
  - an integrated database for sequences, expression data, markers, germplasm and transgenics characteristics

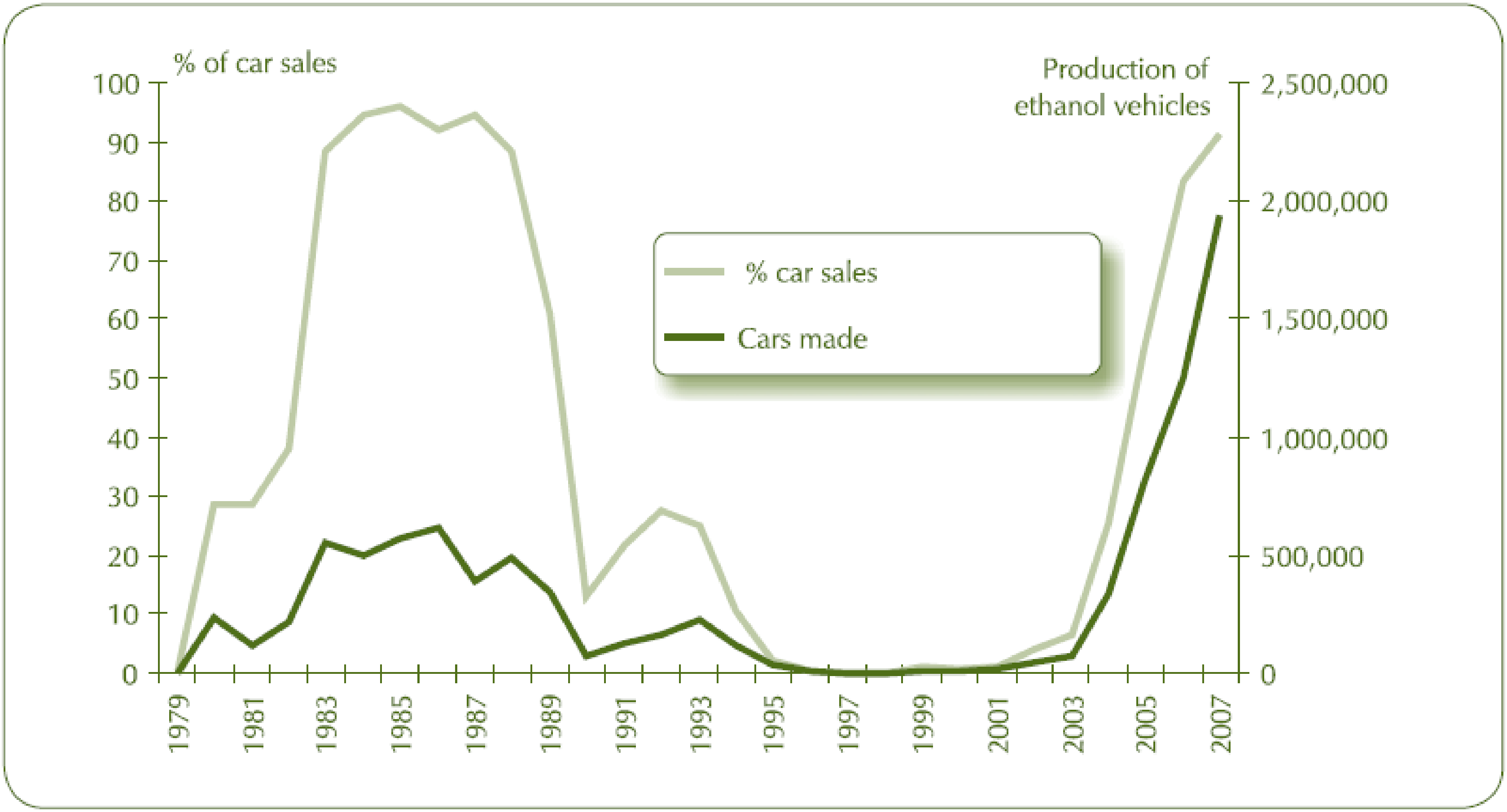

60%
50%
40%
30%
20%
10%
0%
Non-renewable
Renewable
Outras Renováveis
Lenha e Carvão Vegetal
Energia Hidráulica e Eletricidade
Produtos da Cana-de-açúcar
Urânio (U3O8) e Derivados
Carvão Mineral e Derivados
Gás Natural
Petróleo e Derivados

Phases in Brazilian Ethanol

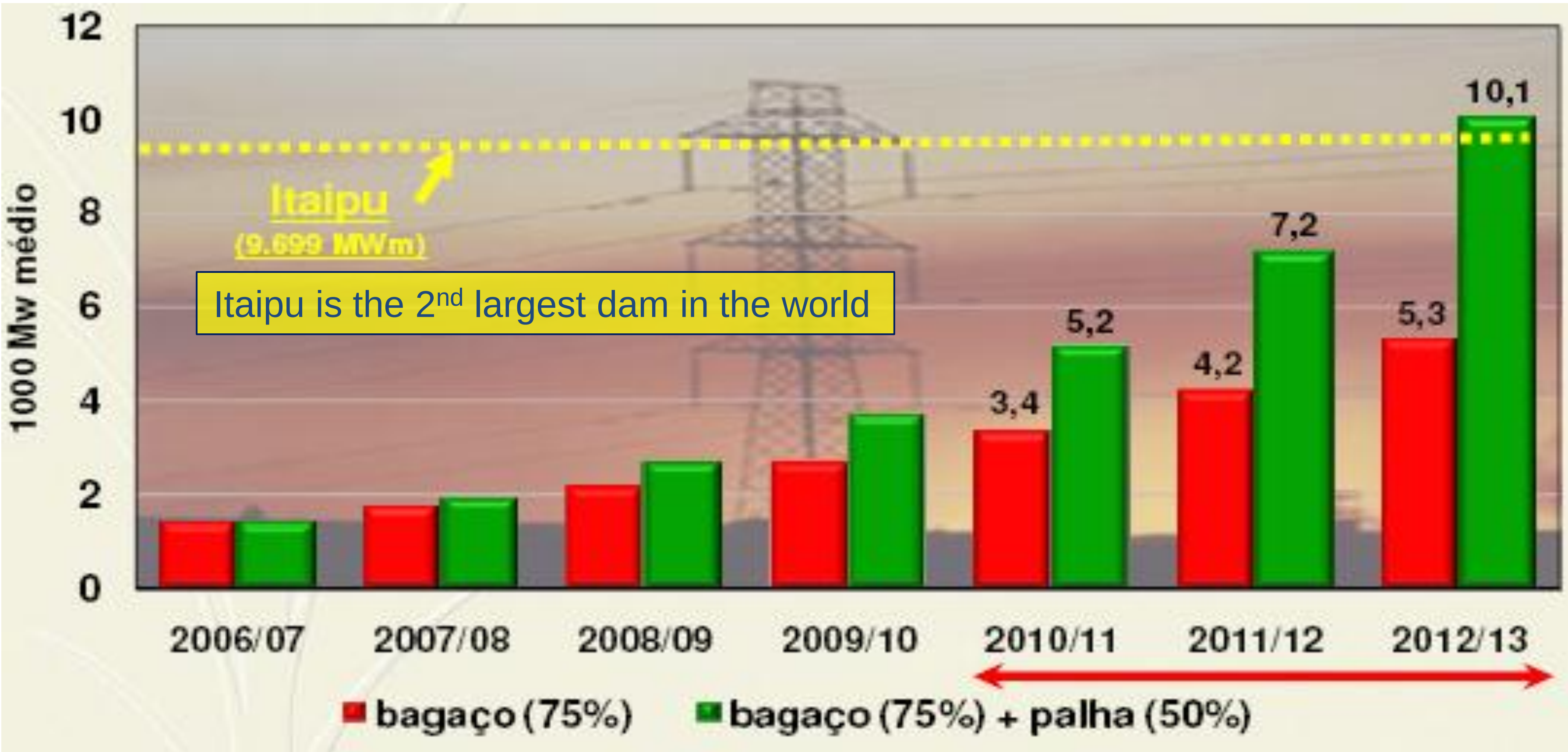


Source: Datagro, 2006. Elaboration: Icone and UNICA

The consumer's view



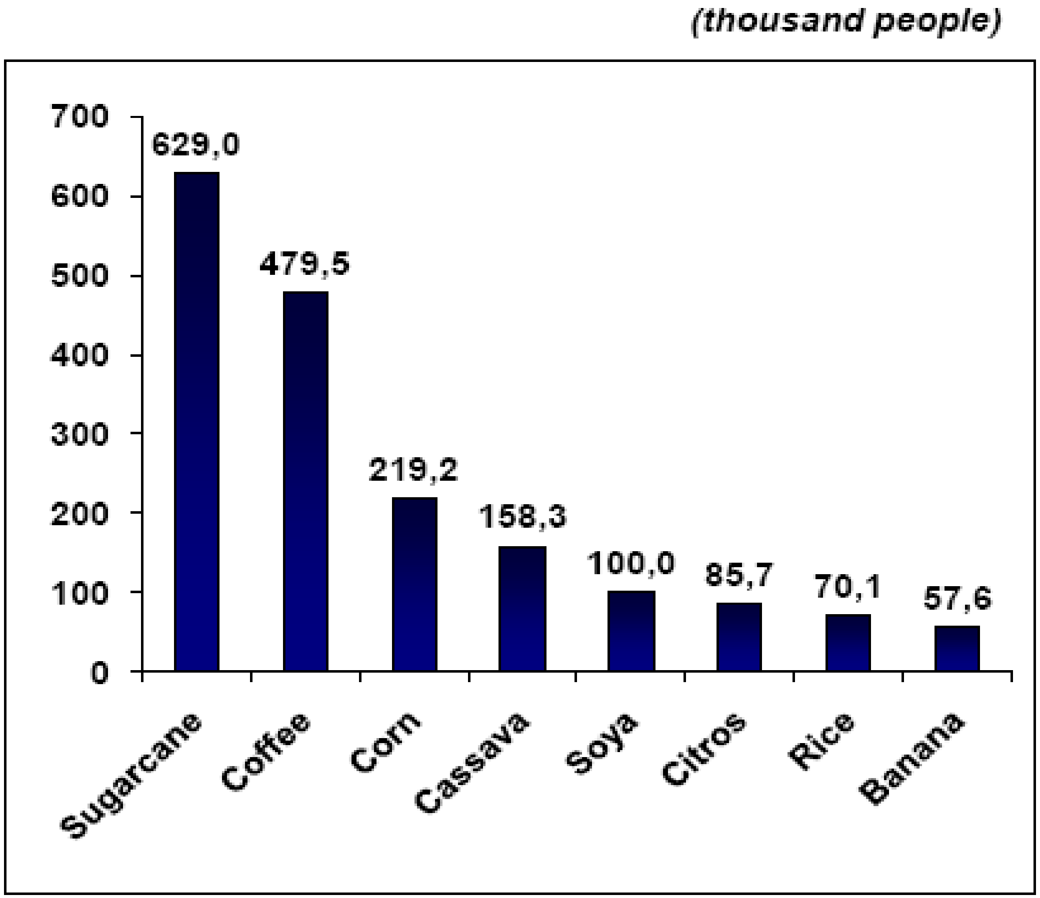
Sugarcane: Ethanol AND Electricity



(Source: UNICA)

Agricultural workers in Brazil

- 2,773,885 agricultural workers in 2008
  - 23% in sugarcane
  - 17% in coffee
  - 8% in corn



Source: Prepared based on data provided by PNAD 2008

Source: Marcia Azanha, "Biofuels and Social Inclusion", www.fapep.br/gsb

Sugarcane agricultural workers schooling and labour rights

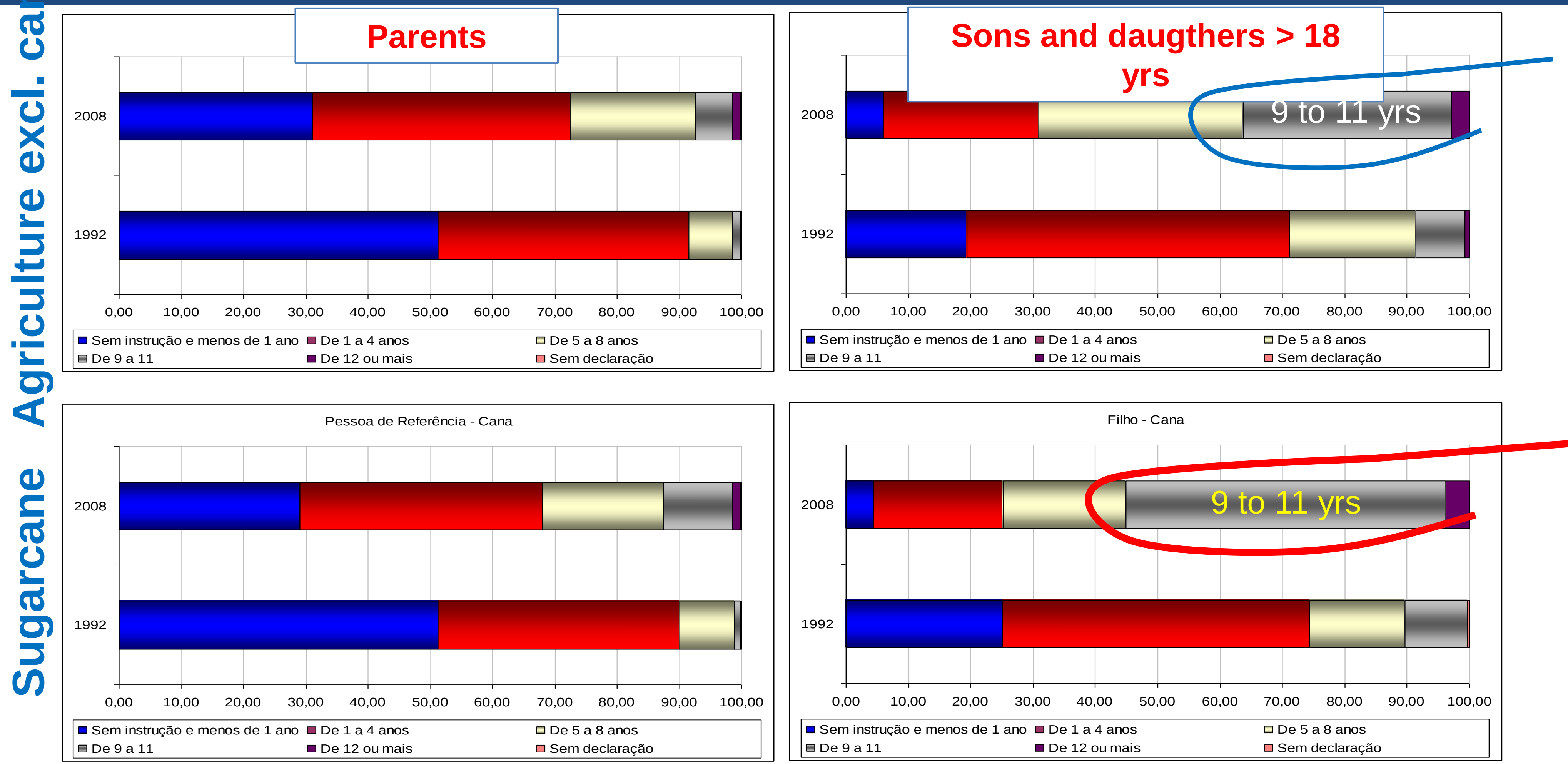
- In agriculture in Brazil
  - 4 years of schooling
- Sugarcane
  - 4.3 years of schooling
  - 24% illiterate

- In Agriculture
  - 40%
- In Sugarcane
  - 81%
- In Sugarcane in SP
  - 95%
- Entitled to
  - Unemployment insurance
  - Paid annual vacation
  - Extra mont pay (13º)

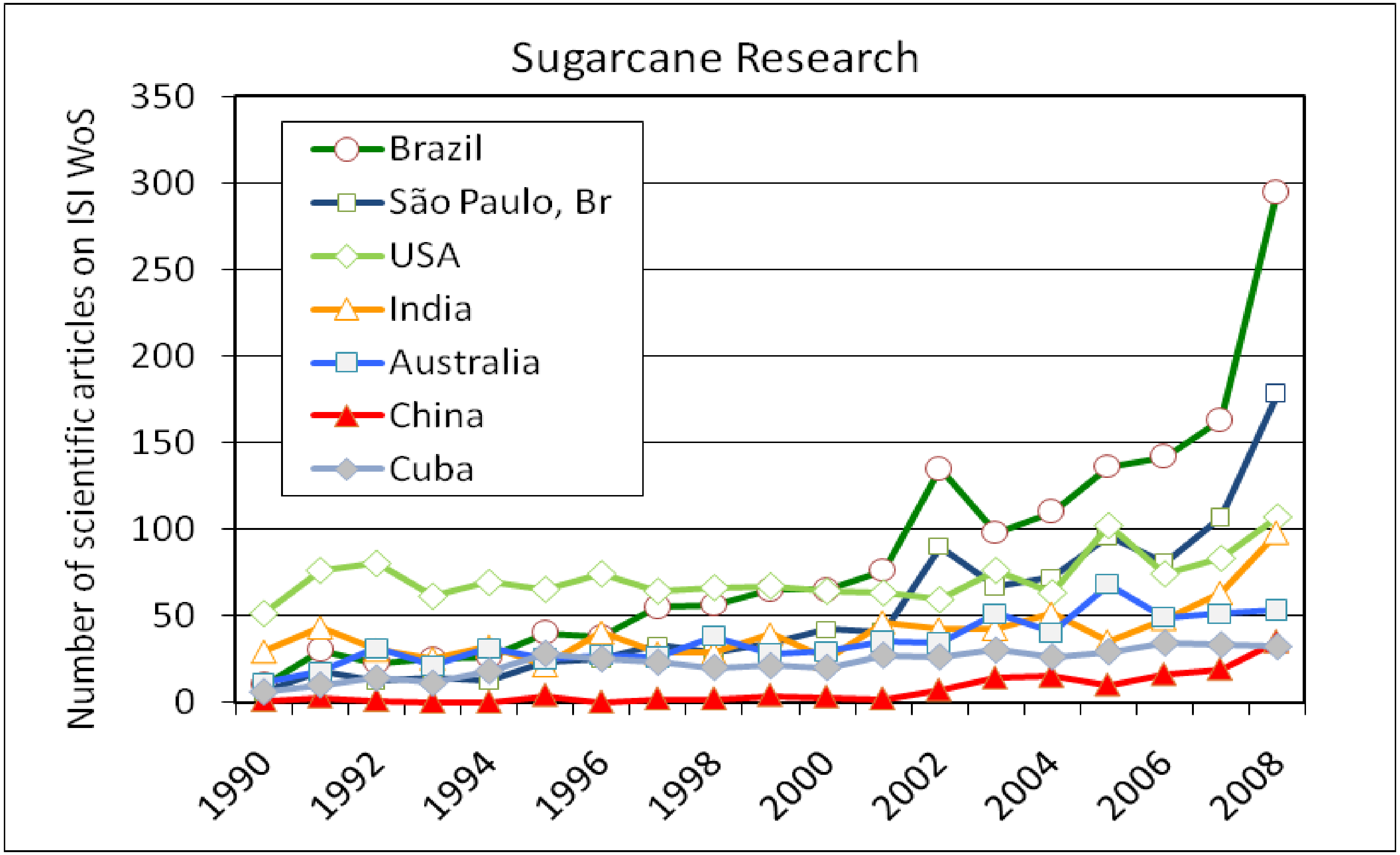
Source: Marcia Azanha, “Biofuels and Social Inclusion”, www.fapep.br/gsb

Children of sugarcane workers gain more years of education

Source: Marcia Azanha, “Biofuels and Social Inclusion”, www.fapep.br/gsb



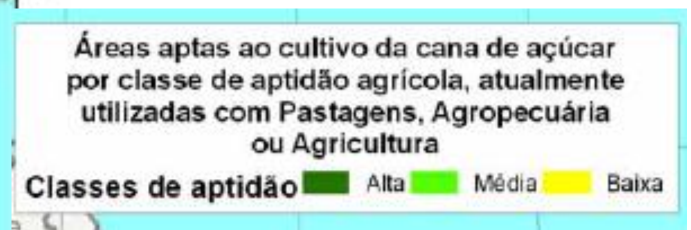
Sugarcane research



Conclusion

- Large scale biofuels are possible now
  - Latin America an Africa have land for 1st generation technology to suceed
  - New science can make it even easier
- S&T advances will make biofuels more widely available
  - Especially for countries with less available land
- In LA and Africa biofuels can be a gateway to growth, development and social inclusion


Boa Vista
R R
A P
Macapá
Belém
São Luís
Manaus
Fortaleza
A M
P A
Teresina
M A
C E
R N
P B
Porto Velho
A C
Rio Branco
P I
Palmas
P E
T O
A L
R O
S E
Aracaju
B A
Peru
M T
Salvador
Cuiabá
G O
Goiânia
Bolivia
M G
Belo Horizonte
Campo Grande
Vitória
E S
M S
Oceano
Pacifico
S P
R J
Rio de Janeiro
São Paulo
P R
Curitiba
Florianópolis
S C
Capitais e Limites
Capital Federal
Capital Estadual
Limite Internacional
Limite Estadual
Bioma Amazônia
Bioma Pantantal
Bacia do Alto Paraguai
R S
Porto Alegre
ESCALA: 1:26.000.000
PROJEÇÃO POLICÔNICA
Meridiano de Referência: 54° W. Gr
Paralelo de Referência: 0°
2009


Áreas aptas ao cultivo da cana de açúcar por classe de aptidão agrícola, atualmente utilizadas com Pastagens, Agropecuária ou Agricultura
Classes de aptidão
Alta
Média
Baixa

Agroecological Zoning, Brazil: available area for cane

Áreas aptas no Brasil por classe de aptidão e tipo de uso						
Brasil	**Classes de Aptidão**	**Áreas aptas por tipo de uso da terra (ha)**			**Área por Aptidão (ha)**	
		Ap	**Ag**	**Ac**	**Ap + Ag**	**Ap + Ag + Ac**
	Alta (A)	11.302.342,95	600.766,55	7.360.310,26	11.903.109,50	19.263.419,76
	Média (M)	22.863.866,09	2.015.247,91	16.344.644,29	24.879.114,00	41.223.758,29
	Baixa (B)	3.041.122,07	483.326,14	731.076,97	3.524.448,21	4.255.525,18
	A+M	34.166.209,05	2.616.014,46	23.704.954,55	36.782.223,51	60.487.178,05
	Total	**37.207.331,12**	**3.099.340,60**	**24.436.031,52**	**40.306.671,72**	**64.742.703,23**

Nota: Classes de Aptidão: A: Alta; M: Média; B: Baixa – Uso atual: Ac: Agricultura; Ag: Agropecuária; Ap: Pastagem.

Relevant organizations

- The São Paulo State Research Foundation, FAPESP: http://www.fapesp.br/english/
- FAPESP's Bioenergy Research Program (BIOEN): http://bioenfapesp.org/
- FAPESP's portfolio of Bioenergy projects as of 2006:

  http://www.fapesp.br/publicacoes/livro_etanol_ing.pdf
- Sugarcane Planters Association, UNICA: http://www.unica.com.br
- Center for Sugarcane Research, CTC: http://www.ctc.com.br
- EMBRAPA Agroenergy: http://www.cnpae.embrapa.br/
- Instituto Agronômico de Campinas, Centro de Pesquisa em Cana:

  http://www.iac.sp.gov.br/Centros/CentroCANA/PRINCIPAL.htm

615 GL of Ethanol will substitute for 30% of the world's gasoline

	2004	2025
Gasoline consumption	1,200 GL	1,700 GL
Ethanol consumption	30 GL	
Ethanol substituting 30% gasoline		615 GL

Área disponível no Brasil: 60 Mha (Zoneamento para Cana, Set 2009, aptidão Alta e Média)

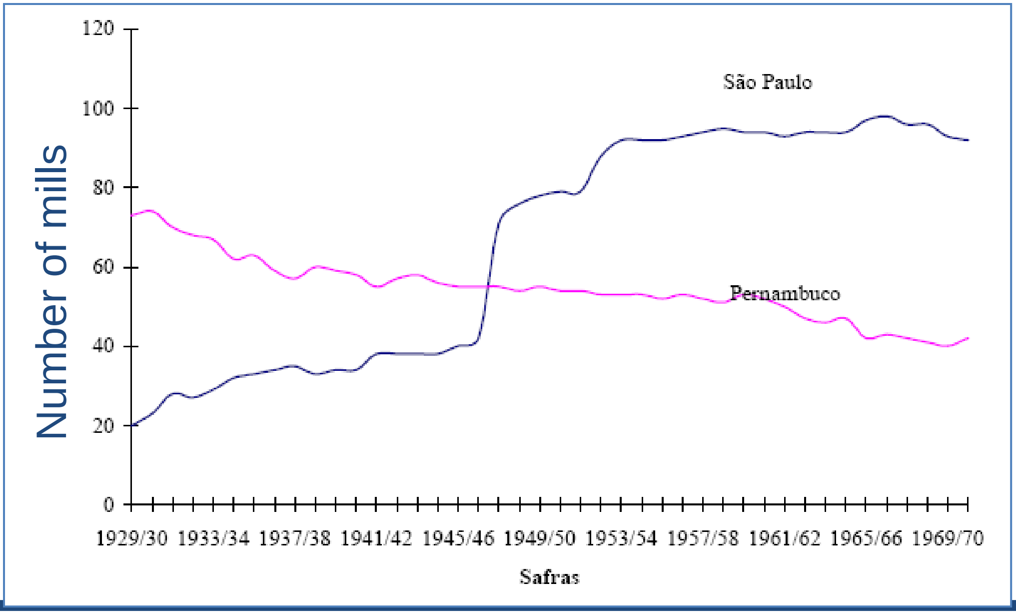
@ 10 kL/Ha (usando somente sacarose da cana) → 600 GL por ano

@ 20kL/Ha (usando sacarose e celulose) → 1.200 GL/ano

From government regulation…

- 1930-1960: government intervention
  - Quotas, prices and criteria for comercialization
  - WW II – 20% ethanol added to gasoline
  - 1946: quotas by state → quotas according to state consumption (sugar)

Source: "M.A.F. Moraes, "The deregulation of the sugar-ethanol sector in Brazil", Doctorate Thesis, ESALQ, USP (1999)



...to more government regulation...

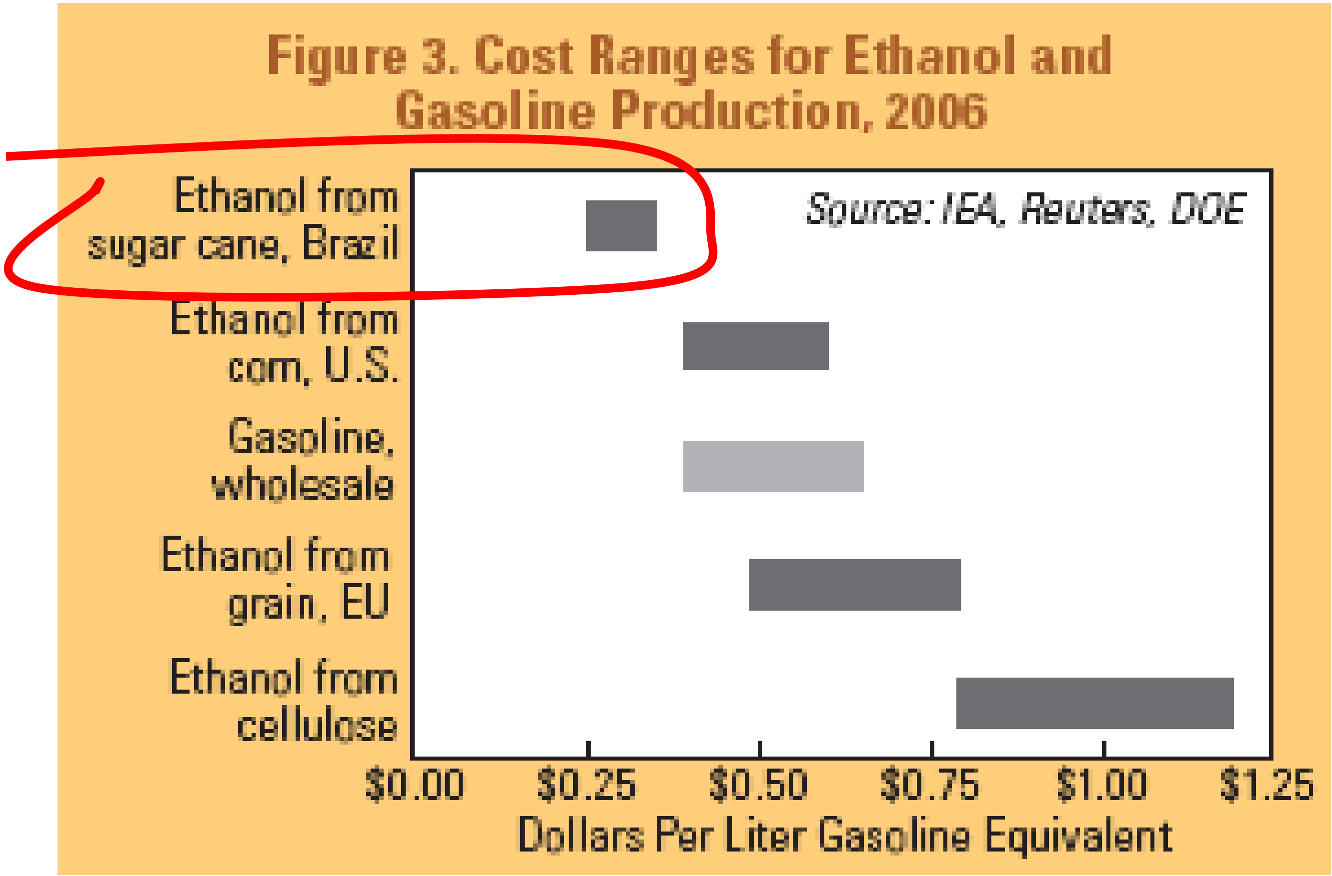
- 1970-1990
  - 1971: Technology for sugar productivity
    - PLANALSUCAR: breeding, mill efficiency
    - Industrial concentration; mergers
  - 1972: Brazil 1st sugar producer in the world
  - 1973: 1st oil shock
  - 1975: ProAlcool (9/10/1975)
    - Government support for new mills and plantations
    - 20% ethanol added to gasoline
  - 1980: 76% of cars sold were ethanol driven → 90% in 1983
  - 1990: macroeconomic crisis, ethanol shortage → end of subsidies

Source: "M.A.F. Moraes, "The deregulation of the sugar-ethanol sector in Brazil", Doctorate Thesis, ESALQ, USP (1999)

....to Deregulation

- 1990 onwards
  - 1996: announcement of end of prices control
  - 1999: end of price control
  - 2003: reduced taxation for Flex-Fuel vehicles
  - Private sector organization
    - UNICA, ORPLANA, ...
  - Sustainability issues
    - Plantation burning for harvesting
    - Zoning

Biofuels costs



World Watch 2006, http://www.worldwatch.org/system/files/EBF008_1.pdf

Less land, less water, less carbon, renewable energy source

"Our goal is to figure out how to produce more with less land, less water and less pollution, so we won't be the only species left living on this planet."

Jason Clay, WWF

- Ethanol from sugarcane
  - Less land: - 4% per year
  - Less water: reuse
  - Less pollution
    - Reduces fossil fuel use
    - Reduces Carbon emissions
  - Use less energy

Ethanol mills can “produce” water

Quinta-feira, Julho 03, 2008 (http://ethanolbrasil.blogspot.com/2008/07/dedini-launches-ethanol-mill-that.html)

Dedini launches ethanol mill that produces water.

Reuters, 07/03/2008.

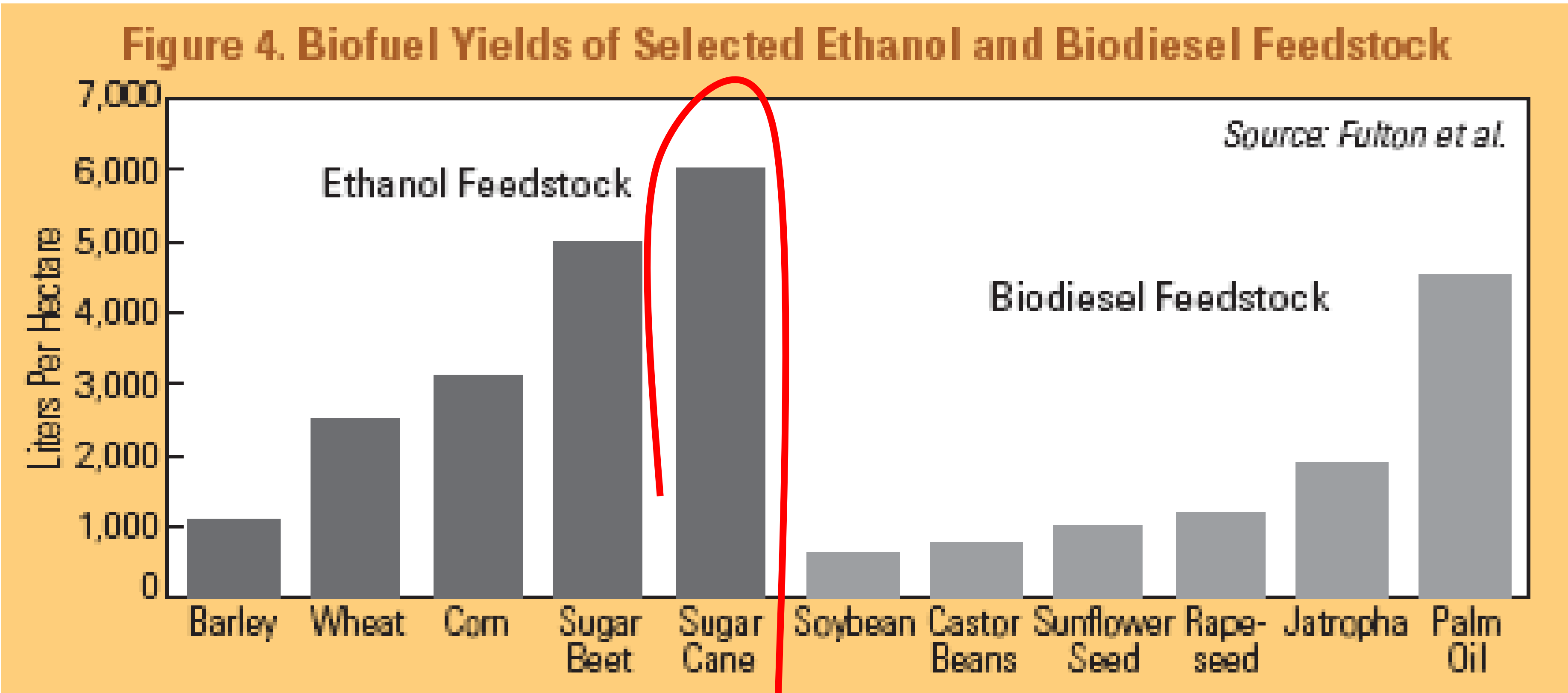
Brazil's Dedini, the leading manufacturer of biofuel equipment, launched a new technology that enables cane-based sugar and ethanol mills to produce water as a byproduct.

Mills in Sao Paulo, Brazil's largest and most efficient cane producing state, consume currently about 1,800 liters of water from rivers or lakes to process each tonne of cane.

Through the use of water contained in cane, the new technology allows mills not only to be self-sufficient but also to sell the product for domestic and industrial usage.

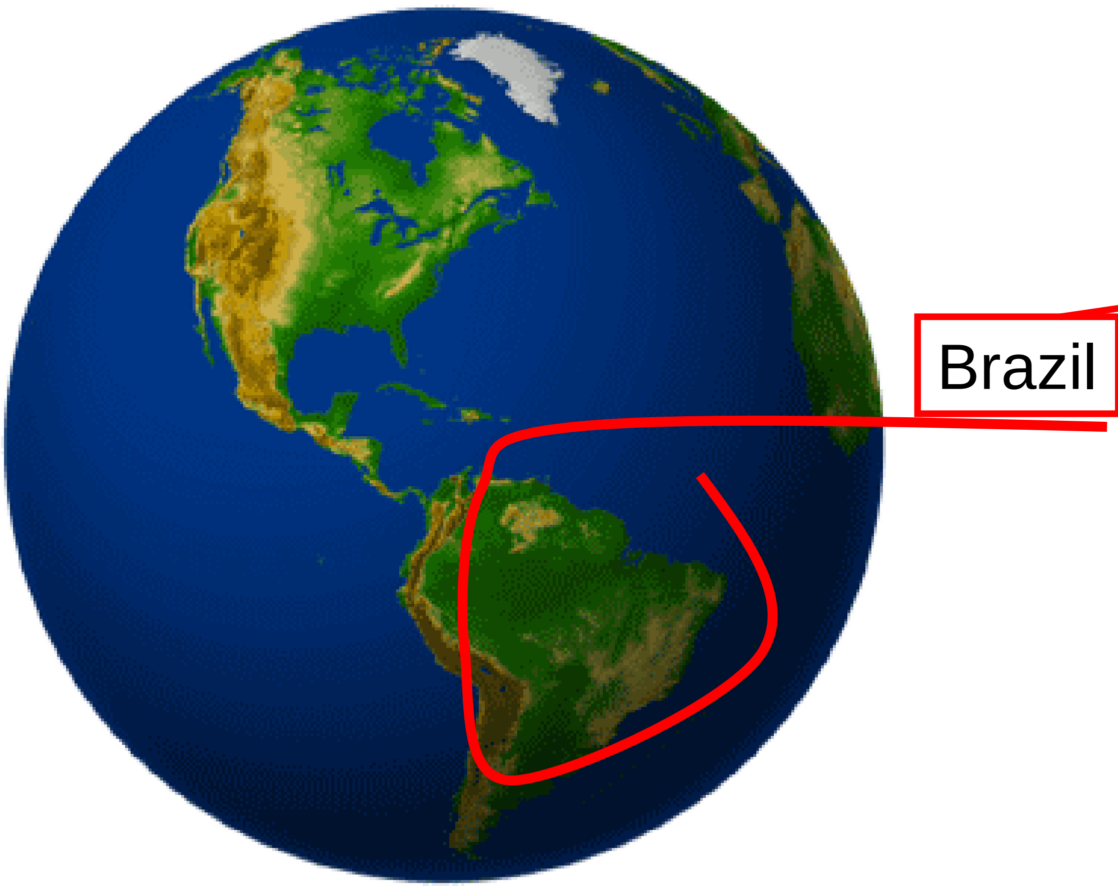
Each tonne of sugar cane contains about 700 kilograms of water. With the new technology, mills could be able to sell up to 300 kilograms of this water per tonne of cane.

Biofuel yield per hectare



World Watch 2006, http://www.worldwatch.org/system/files/EBF008_1.pdf

Brazil: 190 million people, 9th GNP



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