The Brazilian Experience with Sugarcane Bioethanol

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UNICAMP/FAPESP

Global Sustainable Bioenergy African Convention

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PROALCOOL

- **Motivation: to reduce oil imports (80% in 1973, 50% of imports)**
- **Investments: subsidies evaluated in ~US$ 10 billion**
- **Benefits: avoided expenses with oil imports ~US$ 60 billion**

- **<u>Main actions of Proalcool:</u>**

- Parity ethanol and gasoline prices (advantage to ethanol)

- Production Cota: cane, sugar and ethanol

- Prices controlled by the government

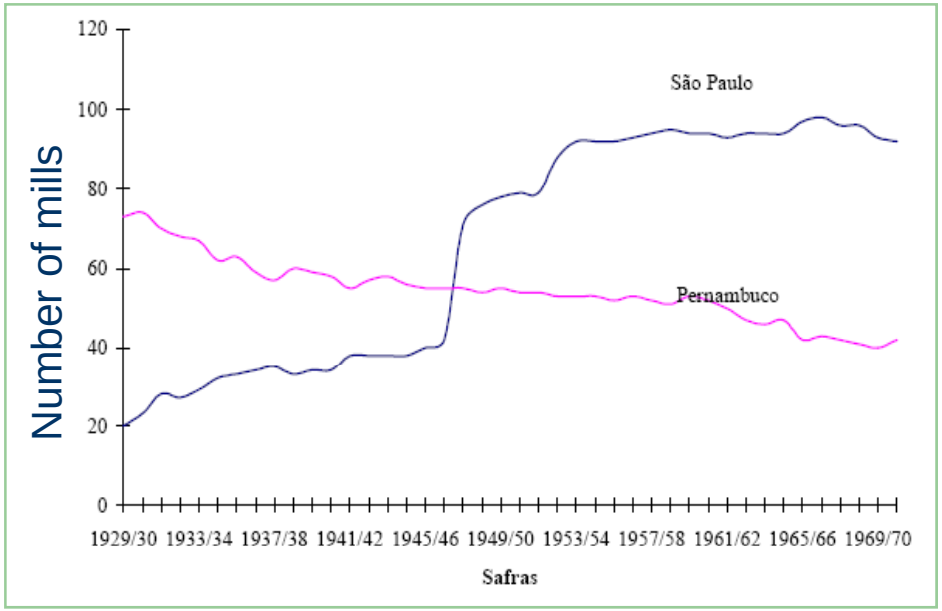
- Reduction of sales tax on ethanol car

- Petrobras bought and distributed ethanol

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...

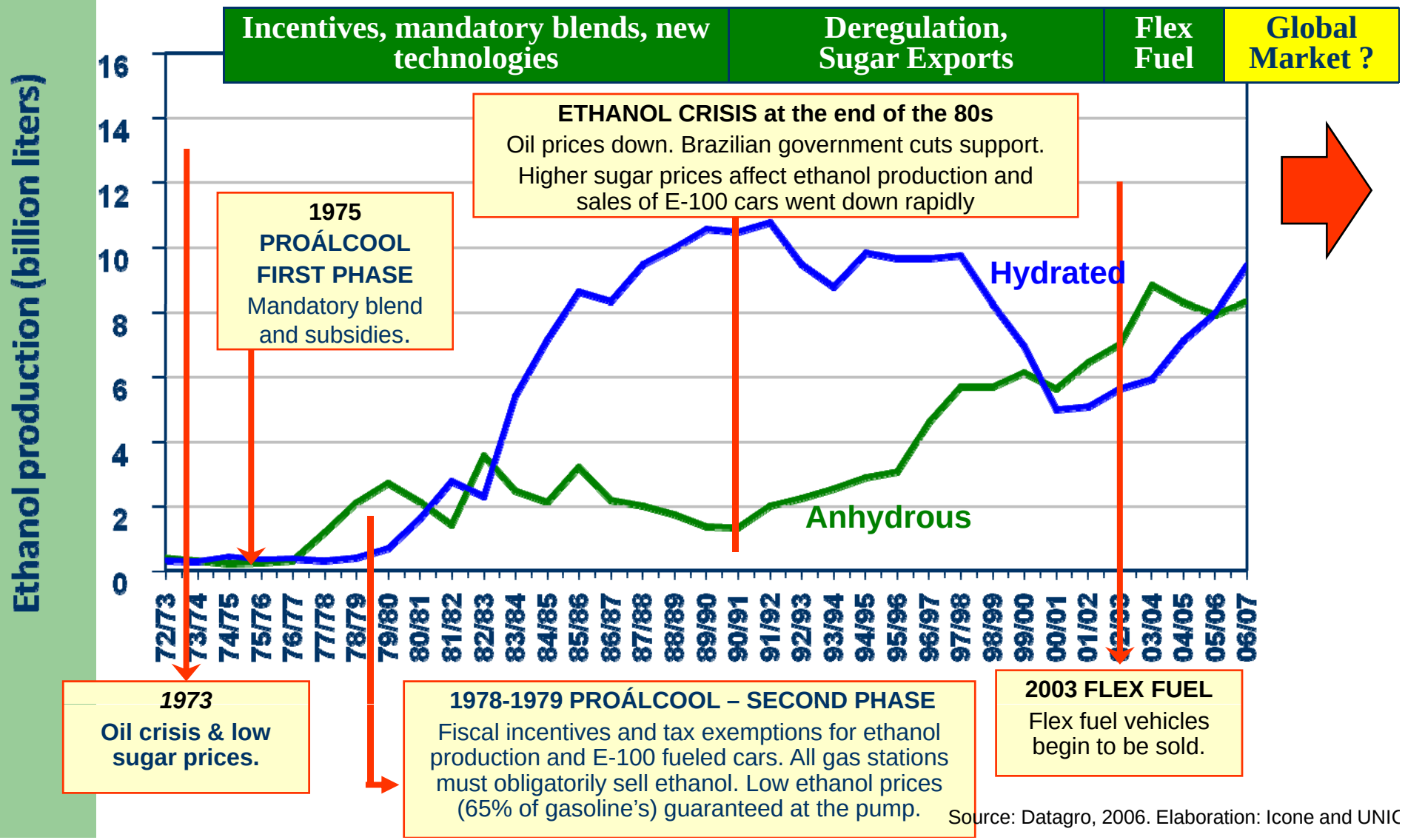
- 1970-1990
  - 1971: Technology for sugar productivity
    - PLANALSUCAR: breeding, mill efficiency
    - Industrial concentration; mergers
  - 1972: Brazil 1st sugar producer in the world
  - 1973: 1st oil shock
  - 1975: ProAlcool (9/11/1975)
    - Government support for new mills and plantations
    - 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

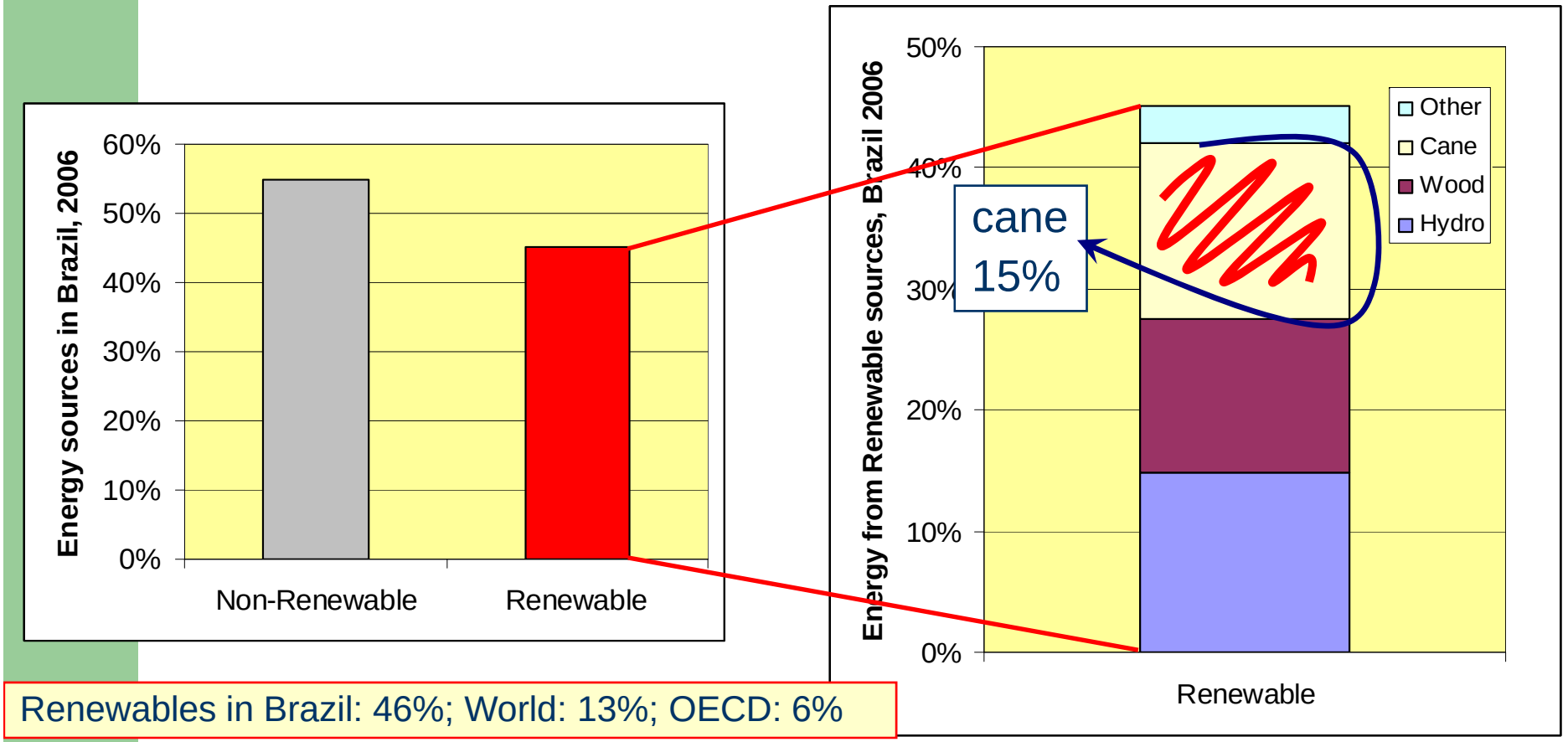
- 1990 onwards
  - 1996: announcement of end of prices control
  - 1999: end of price control
  - 2003: reduced taxation for Flex-Fuel vehicles
  - Private sector organization
    - UNICA, ORPLANA, ...
  - Sustainability issues
    - Plantation burning for harvesting
    - Zoning

Phases in Brazilian Ethanol



Source: Datagro, 2006. Elaboration: Icone and UNIC

46% of Brazil's energy comes from renewable sources

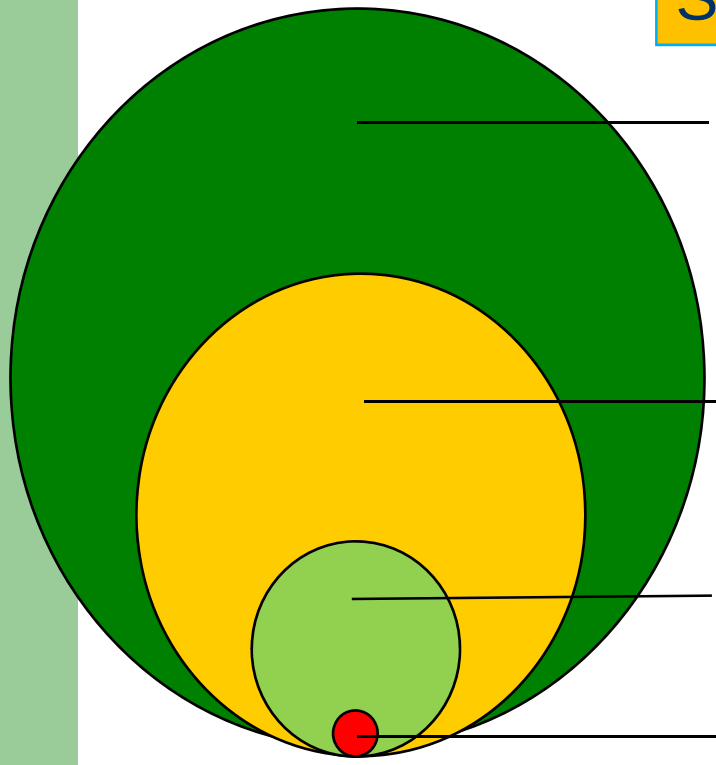


Renewables in Brazil: 46%; World: 13%; OECD: 6%

Source: MME-BEN (2007)

Sugarcane for ethanol uses 0.5% of total area

Small bioenergy footprint



Total country area (851 Mha, 100%)

Rural properties area (355 Mha, 42%)

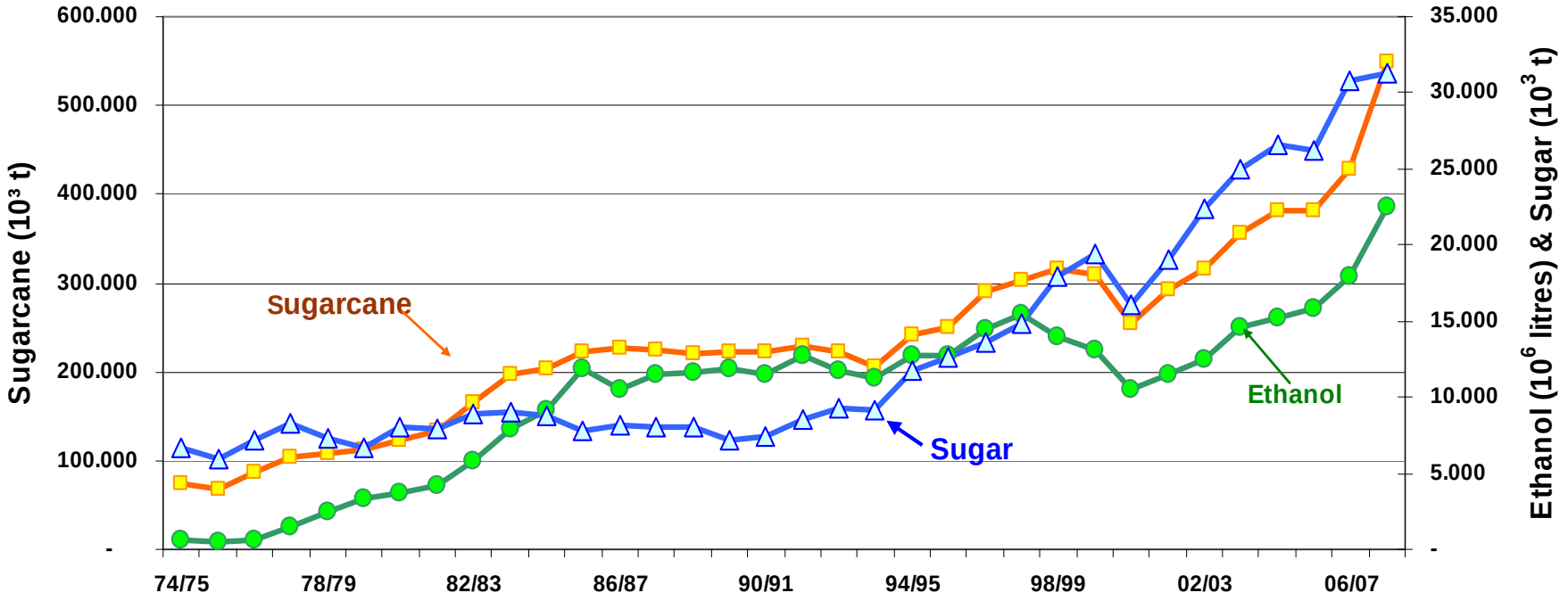
Area used for agriculture (76.7 Mha, 9%)

Area used for sugarcane for ethanol (3.4 Mha, 0.4%)

Source: Horta Nogueira and Seabra (2008)

Brazilian Cane, Sugar and Ethanol Production

Evolution of Production: sugarcane, sugar and ethanol



Brazil increased ethanol production and the same time that increased its sugar production

Source: UNICA

Ethanol and Biodiesel GHG Reduction at Production Level

Biofuel/Crop	GHG Emission Reduction
Ethanol[1]	
Sugarcane	90 %
Lignocellulose	70 - 90 %
Sugar beet	40 - 50 %
Maize	13 %
Biodiesel[2]	
Rapeseed/soybeans	40 - 50 %
Palm oil	35 %

Source: Doornbosch and Steenblik

Notes: 1. Compared with gasoline; 2. Compared with mineral diesel

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

Isaias C. Macedo[a,*], *Joaquim E.A. Seabra*[b], *João E.A.R. Silva*[c]

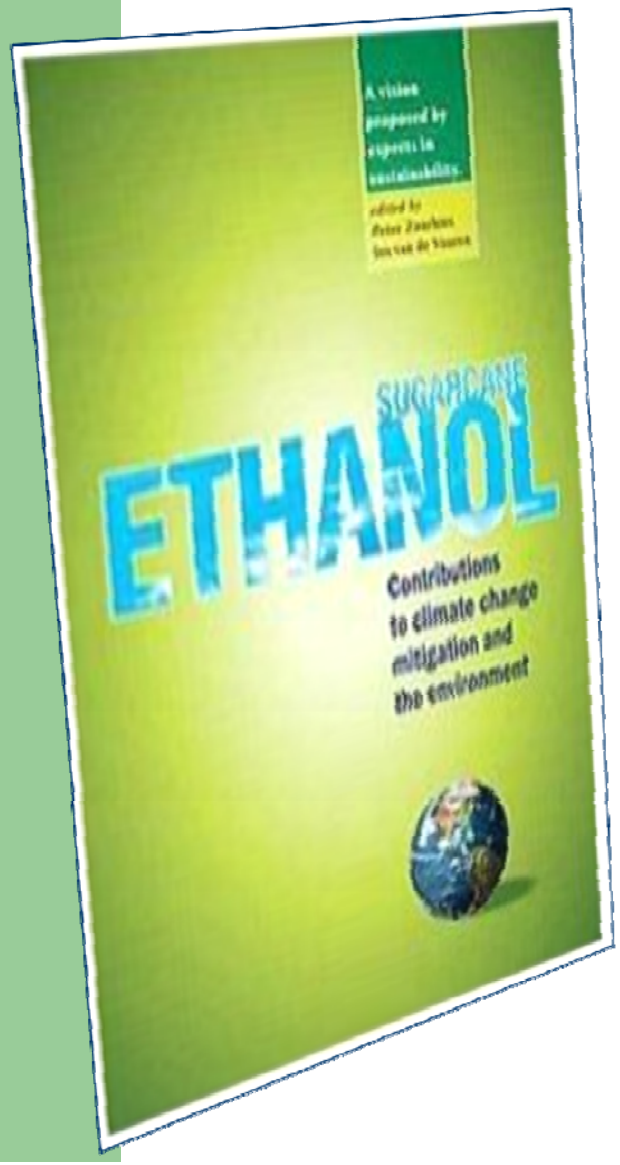
[a]*Interdisciplinary Center for Energy Planning (NIPE), State University of Campinas (Unicamp), CEP 13084-971, Campinas, SP, Brazil*
[b]*College of Mechanical Engineering, State University of Campinas, Cidade Universitária “Zeferino Vaz”, CEP 13083-970, Barão Geraldo, Campinas-SP, Brazil*
[c]*Centro de Tecnologia Canavieira (CTC), CEP 13400-040, Piracicaba, SP, Brazil*

Avoided emissions due to ethanol use (t CO_2 eq/m^3 hydrous or anhydrous; substitution criterion for the co-products)

	Ethanol use [a]	Avoided emissions [b]	Net emission [c]
	E100	-2.0	-1.7
	E25	-2.1	-1.8
	E100	-2.0	-2.4
	FFV	-1.8	-2.2
	E25	-2.1	-2.5
	E100	-2.0	-1.9
	FFV	-1.8	-1.7
	E25	-2.1	-2.0

Source: Macedo IC, Seabra JEA, 2009

Sugarcane ethanol: Energy balance and GHG emissions

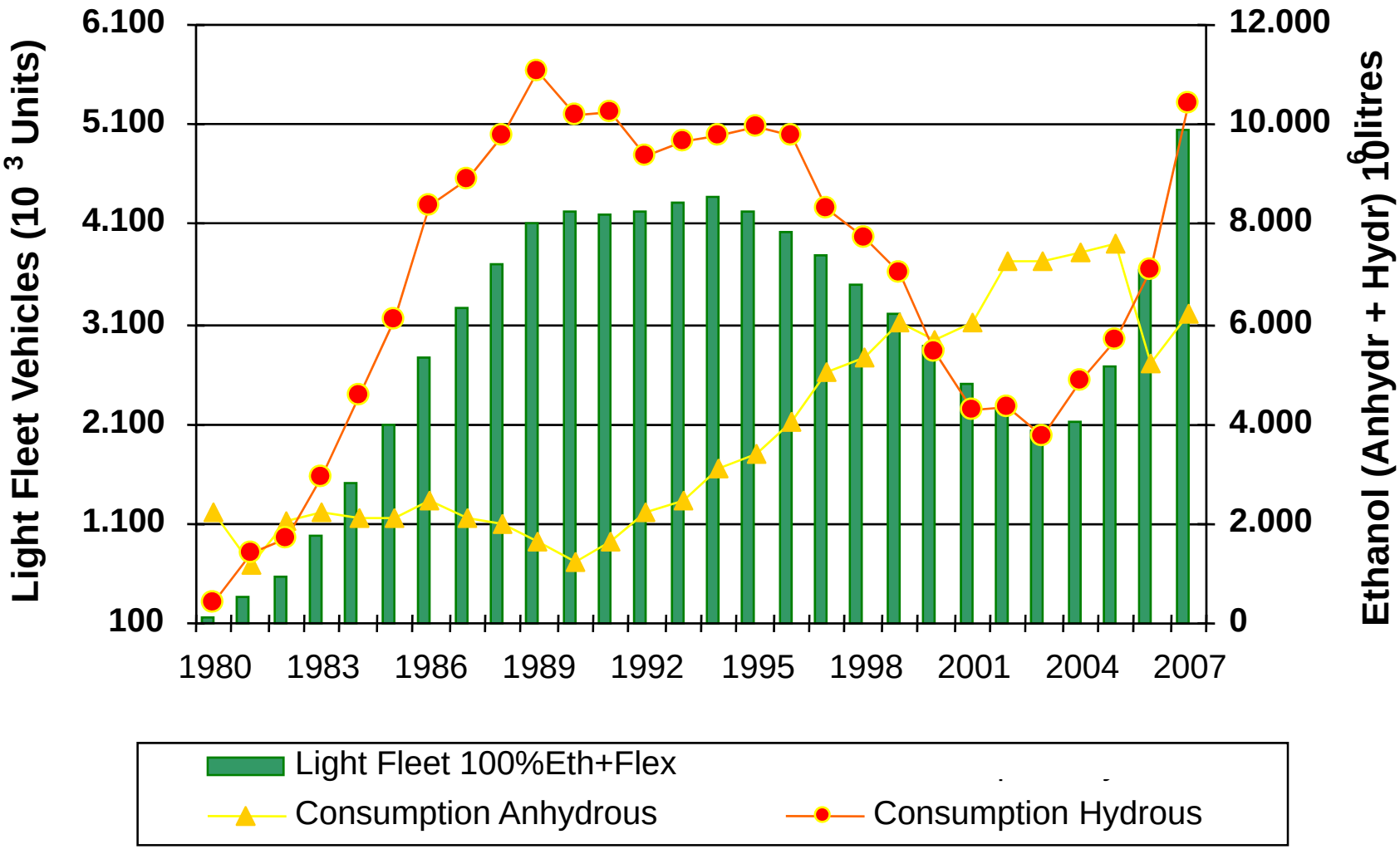


- ✓ **Macedo and Seabra (2008)**:
  - **2006**: 44 mills (~100 Mtc/year) of Brazilian C-S Region – data from CTC Mutual Control.
  - **2020 Electricity Scenario**: trash recovery (40%) and surplus power production with integrated commercial, steam based cycle (CEST system).
  - **2020 Ethanol Scenario**: trash recovery and ethanol production from biochemical conversion of surplus biomass in a hypothetical system integrated to the mill.

Present Situation of Ethanol in Brazil

- Brazil produces sugar and ethanol at lowest cost in the world
- Sugarcane ethanol presents the best energy balance among biofuels
- It also is the best alternative to mitigate GHG emissions
- 50% of liquid fuels utilized in light vehicles fleet in Brazil
- Ethanol is sold all over Brazil
- Ethanol & bagasse represents 17% of Brazilian Energy Matrix (more than hydroelectricity-13%)
- Generates nearly 750 thousand direct jobs in Brazil
- Important contribution to Brazilian GDP

Light fleet vehicles and Consumption of Ethanol (Hydrous and Anhydrous)



Automotive Use of Ethanol in Brazil

- In Brazil there is no pure gasoline; only E25, E100 and flex
- 50% of light vehicle fleet (around 26 billion liters in 2009)
- Flex vehicles accounts for 90% of sales of new vehicles
- All models manufactured in Brazil have flex version
- Average price of pure ethanol is US$ 0.70-0.80 at the pump station and E25 is US$ 1.20-1.50; ethanol production cost approx US$ 0.70-0.80/liter at the mill
- At the distributor ethanol price is US$ 37/GJ and “E25 gasoline 43/GJ”
- Today, liquid emissions of CO_2 is 75g/km for the entire light vehicle fleet in Brazil; In Japan is expected to be 120g/km in 2013 (in São Paulo city is 35g/km due to larger use of ethanol)

Brazilian Ethanol: reasons for success

- Brazil established a dynamic relation between Research and Production particularly after 1975, involving govmt and private sectors
- Sugarcane, an excellent energy crop
- Creation of the "**Brazilian Model**" combining efficient sugar and ethanol production

Expanding Ethanol Production

- But the present questions are:
- **How much sustainable ethanol can Brazil produce**?
- What are the limits without touching the Amazon and other eco santuaries?
- What could be the sugarcane ethanol contribution to decrease GHG emissions?
- What research can we do to improve cost and sustainability indicators?

NIPE-Unicamp Ethanol Project

- **Coordinator**:
  - Professor Rogério Cezar de Cerqueira Leite (UNICAMP)

- Vice-Coordinators:
  - Dr. Manoel Sobral Jr (phase I)
  - Dr. Manoel Regis Lima Verde Leal (phases I e II)
  - Dr. Luís Cortez (phase III)

  - **9 senior researchers**, around **20 researchers involved**

  - **Collaboration**: CGEE, MCT, MAPA, EMBRAPA, TRANSPETRO, PETROBRAS, DEDINI, CTC

  - Project in agreement with the Brazilian Agro energy Policy

Source: Leite et al. 2009
Energy 34(2009) 655-661

Objectives

- **OE1**: **Present technology** and possible improvements **(**M. Regis Leal, E.Gomez**)**
- **OE2**: Assessment of **new technologies** (C. Rossell, A, Walter, and O. Braunbeck)
- **OE3**: Selection of **potential suitable areas** for sugarcane production in Brazil (M. Regis Leal)
- **OE4**: **Infra-Structure: existing and need for improvement and expansion** (M. Scandiffio)
- **OE5**: Assessment of **socio-economic impacts** (J.Scaramucci, M. Cunha)
- **OE6**: Construction of **ethanol production scenarios and socio-economic impacts** (A. Furtado)
- **OE7**: Assessment of **environmental impacts** (G. Jannuzzi)
- **OE8**: **Legislation and policies** in different countries: producers and buyers (M. Sobral Jr.)

Source: Leite et al. 2009
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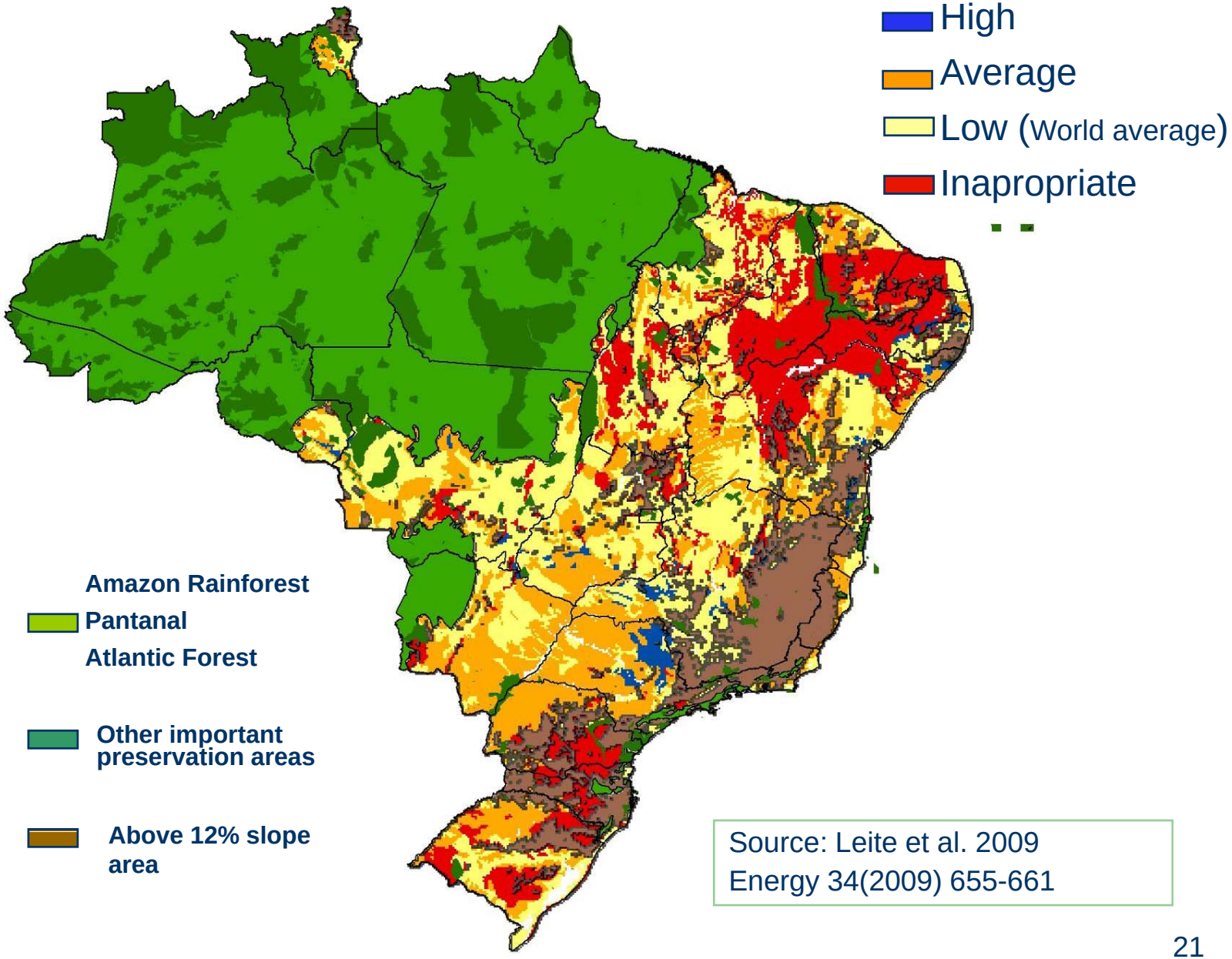
POTENTIAL FOR SUGAR CANE PRODUCTION: SOIL AND CLIMATE - **WITHOUT IRRIGATION**



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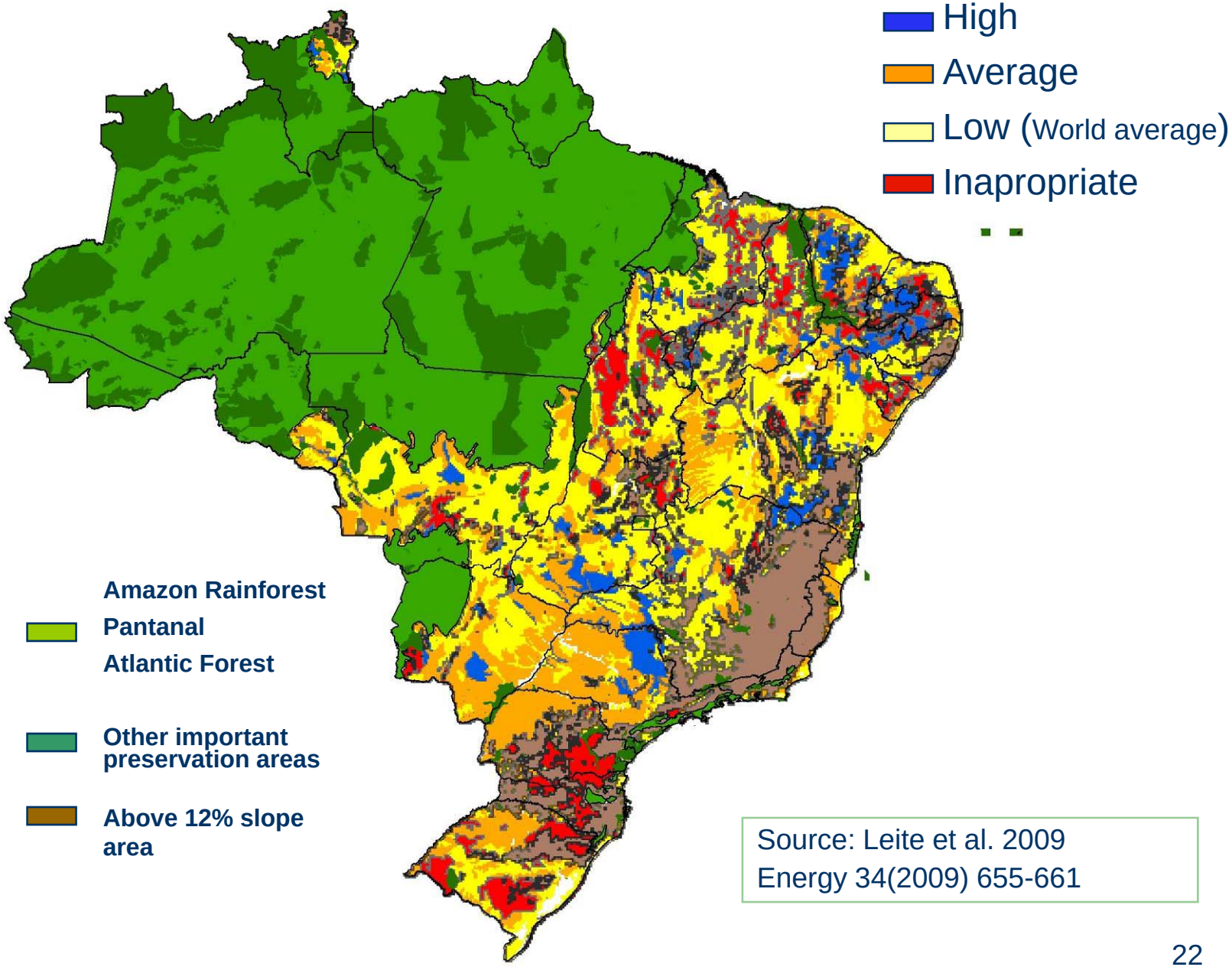

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Summary
Gasoline substitution of 5% in 2025

Investments in 20 years

Agricultural + Industrial + logistics	**~ US$ 5 billion/year**

Results

Ethanol production	**104 billion liters/year in 2025**
Production of electricity	**50,000 GWh/year => 15% of 2004**
Production in Brazil in 2004	**365,000 GWh/year**
Income from Exports in 2025	**US$ 31 billion**
Increase in GDP (2025)	**US$ 75 billion**

Including direct, indirect and induced revenue (input-output matrix)

Increase Jobs	**5.3 million**
Average wage	**50% above national average**

Source: Leite et al. 2009
Energy 34(2009) 655-661

Sugarcane Zoning in Brazil

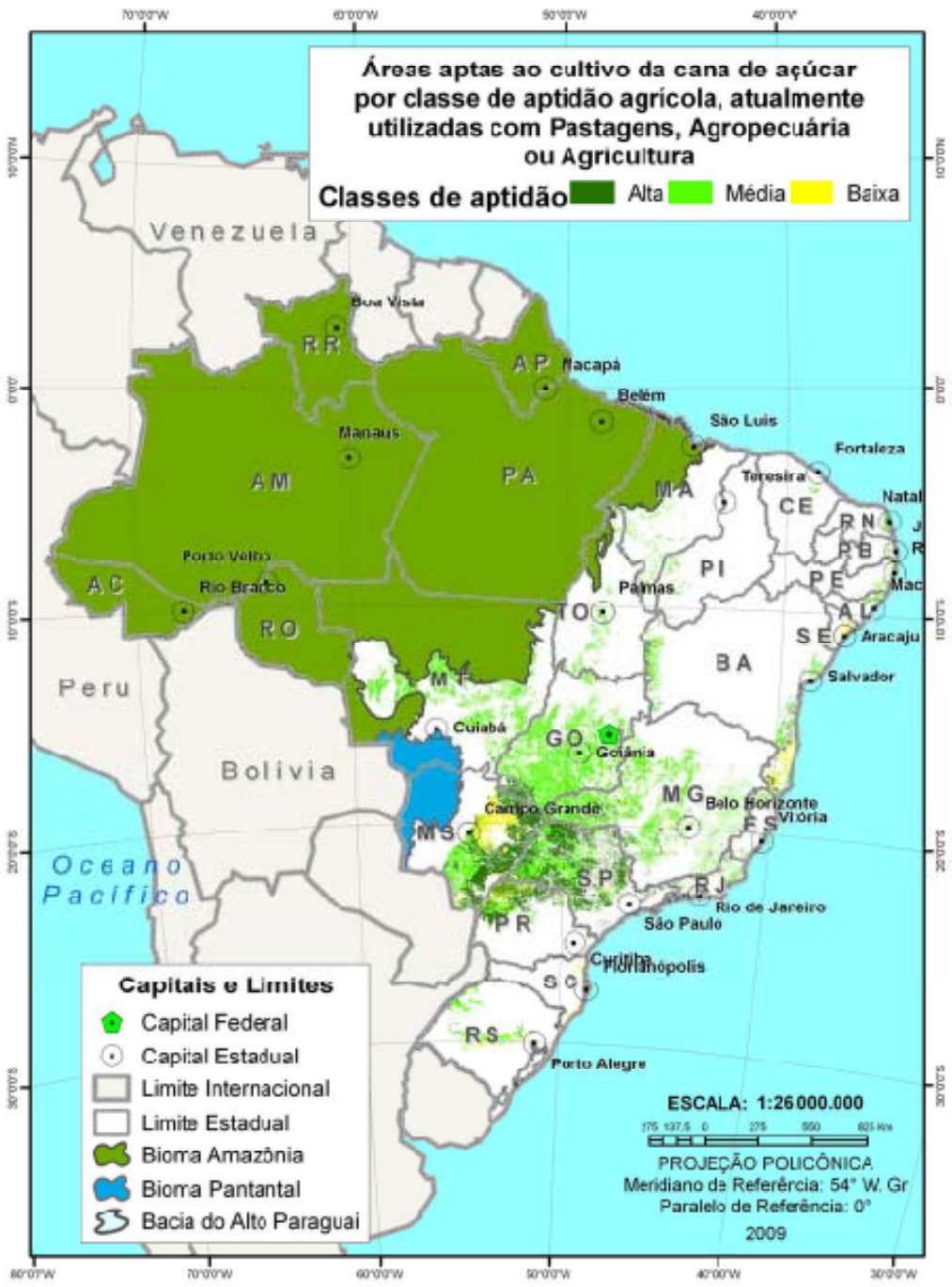
Tabela 7 - Síntese das áreas aptas para a expansão do cultivo da cana-de-açúcar no Brasil, considerando as classes de aptidão agrícola e os tipos de uso da terra predominantes em 2002.

Brasil	Classes de aptidão	Áreas aptas por tipo de uso da terra por classe de aptidão (ha)				
		Ap	Ag	Ac	Ap + Ag	Ap + Ag + Ac
Áreas totais para o Brasil	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	2.126.394,55	16.496.735,67	24.990.260,64	41.486.996,31
	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	2.727.161,10	23.857.045,93	36.893.370,15	60.750.416,07
	A+M+B	37.207.331,12	3.210.487,24	24.588.122,90	40.417.818,36	65.005.941,25

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

Source: Ministério da Agricultura, Pecuária e Abastecimento. Zoneamento Agroecológico da Cana-de-Açúcar. 2009


Áreas aptas ao cultivo da cana-de-açúcar com aptidão agrícola ALTA, MÉDIA ou BAIXA, atualmente utilizadas com Pastagens, Agropecuária ou Agricultura
Áreas aptas ao cultivo
Venezuela
Oceano Atlântico
Peru
Bolivia
Oceano Pacífico
Boa Vista
Macapá
Belém
São Luís
Fortaleza
Manaus
Teresina
Natal
Porto Velho
Rio Branco
Palmas
Aracaju
Salvador
Goiânia
Campo Grande
Belo Horizonte
Vitória
Rio de Janeiro
São Paulo
Curitiba
Florianópolis
Porto Alegre
RR
AP
AM
PA
MA
CE
RN
PB
PE
AL
SE
PI
AC
RO
TO
BA
MT
GO
MG
ES
MS
SP
RJ
PR
SC
RS
Capitais e Limites
Capital Federal
Capital Estadual
Limite Internacional
Limite Estadual
Bioma Amazônia
Bioma Pantantal
Bacia do Alto Paraguai
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
Venezuela
Peru
Bolivia
Oceano Pacífico
Boa Vista
Macapá
Belém
São Luis
Fortaleza
Manaus
Teresina
Natal
Porto Velho
Rio Branco
Palmas
Aracaju
Salvador
Cuiabá
Goiânia
Campo Grande
Belo Horizonte
Vitória
São Paulo
Rio de Janeiro
Curitiba
Florianópolis
Porto Alegre
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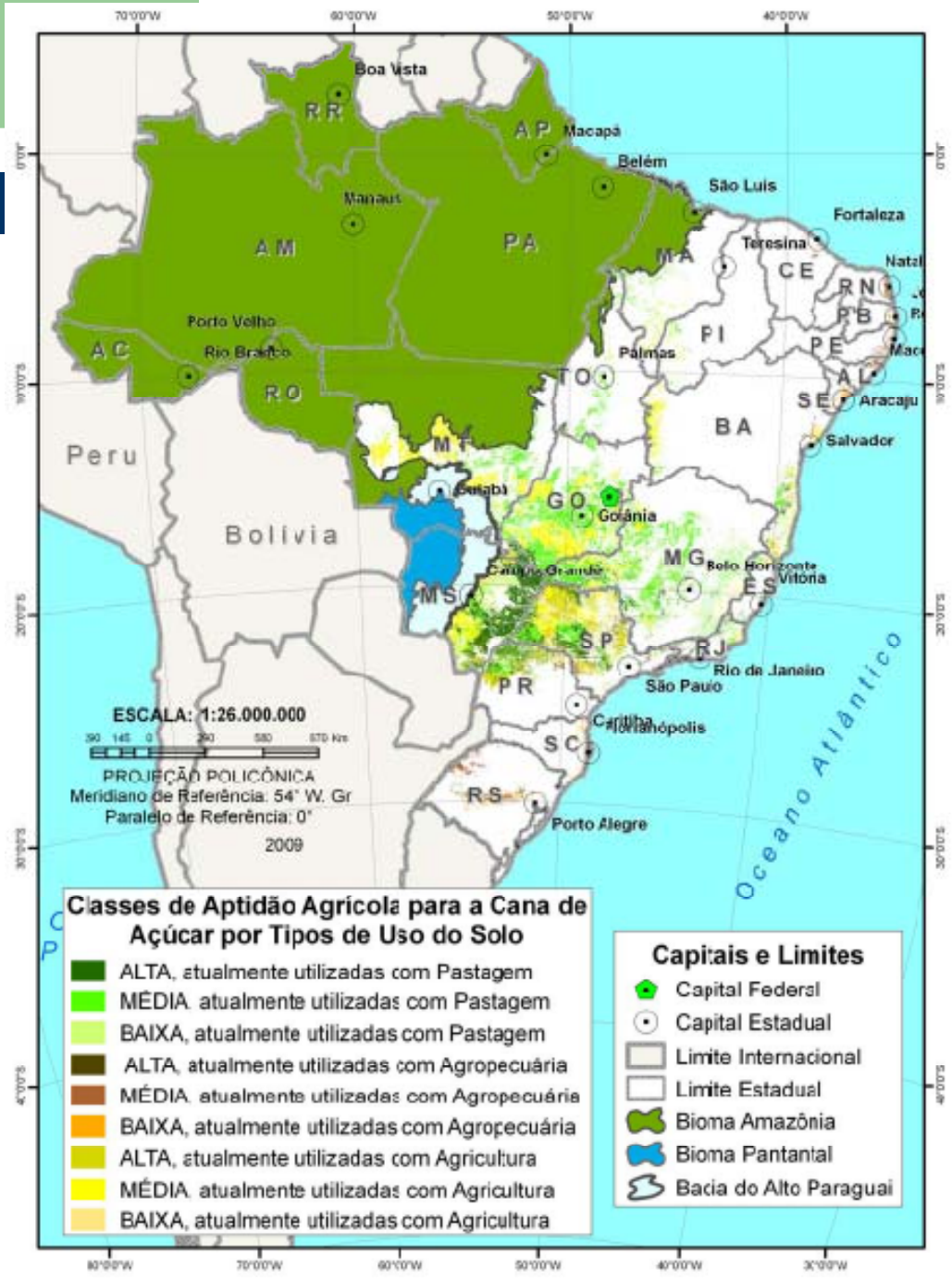
PR
SC
RS
Capitais e Limites
Capital Federal
Capital Estadual
Limite Internacional
Limite Estadual
Bioma Amazônia
Bioma Pantantal
Bacia do Alto Paraguai
ESCALA: 1:26.000.000
PROJEÇÃO POLICÔNICA
Meridiano de Referência: 54° W. Gr
Paralelo de Referência: 0°
2009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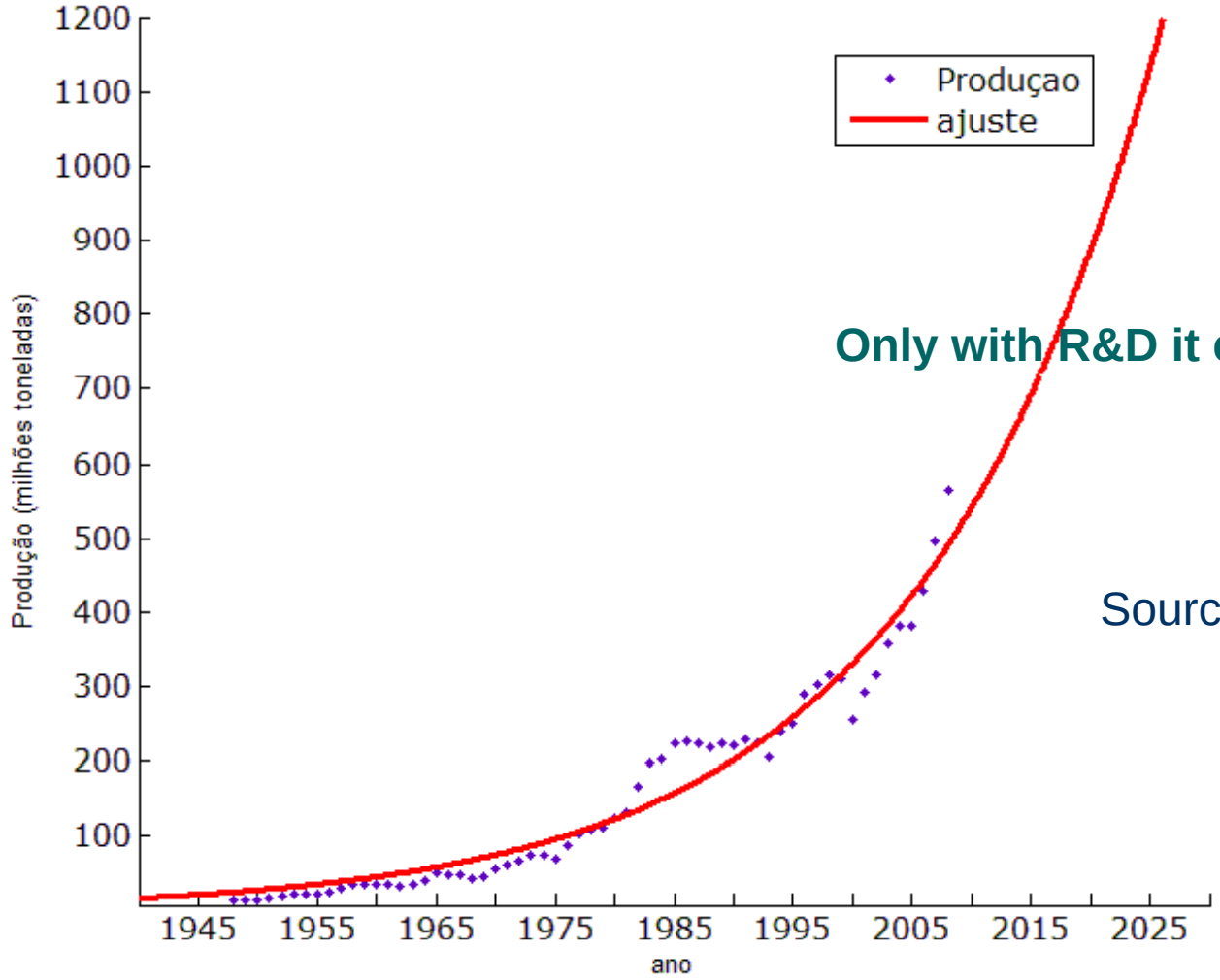
Oceano Atlântico
ESCALA: 1:26.000.000
PROJEÇÃO POLICÔNICA
Meridiano de Referência: 54° W. Gr
Paralelo de Referência: 0°
2009
Classes de Aptidão Agrícola para a Cana de Açúcar por Tipos de Uso do Solo
ALTA, atualmente utilizadas com Pastagem
MÉDIA, atualmente utilizadas com Pastagem
BAIXA, atualmente utilizadas com Pastagem
ALTA, atualmente utilizadas com Agropecuária
MÉDIA, atualmente utilizadas com Agropecuária
BAIXA, atualmente utilizadas com Agropecuária
ALTA, atualmente utilizadas com Agricultura
MÉDIA, atualmente utilizadas com Agricultura
BAIXA, atualmente utilizadas com Agricultura
Capitais e Limites
Capital Federal
Capital Estadual
Limite Internacional
Limite Estadual
Bioma Amazônia
Bioma Pantanal
Bacia do Alto Paraguai

Expected expansion of sugarcane production in Brazil



Only with R&D it can be sustainable!

Source: MAPA, 2009