Aggregating science and technology to a traditional agro-industry, ethanol from sugarcane became a sustainable and competitive alternative for the current and future energy supply.

Outline

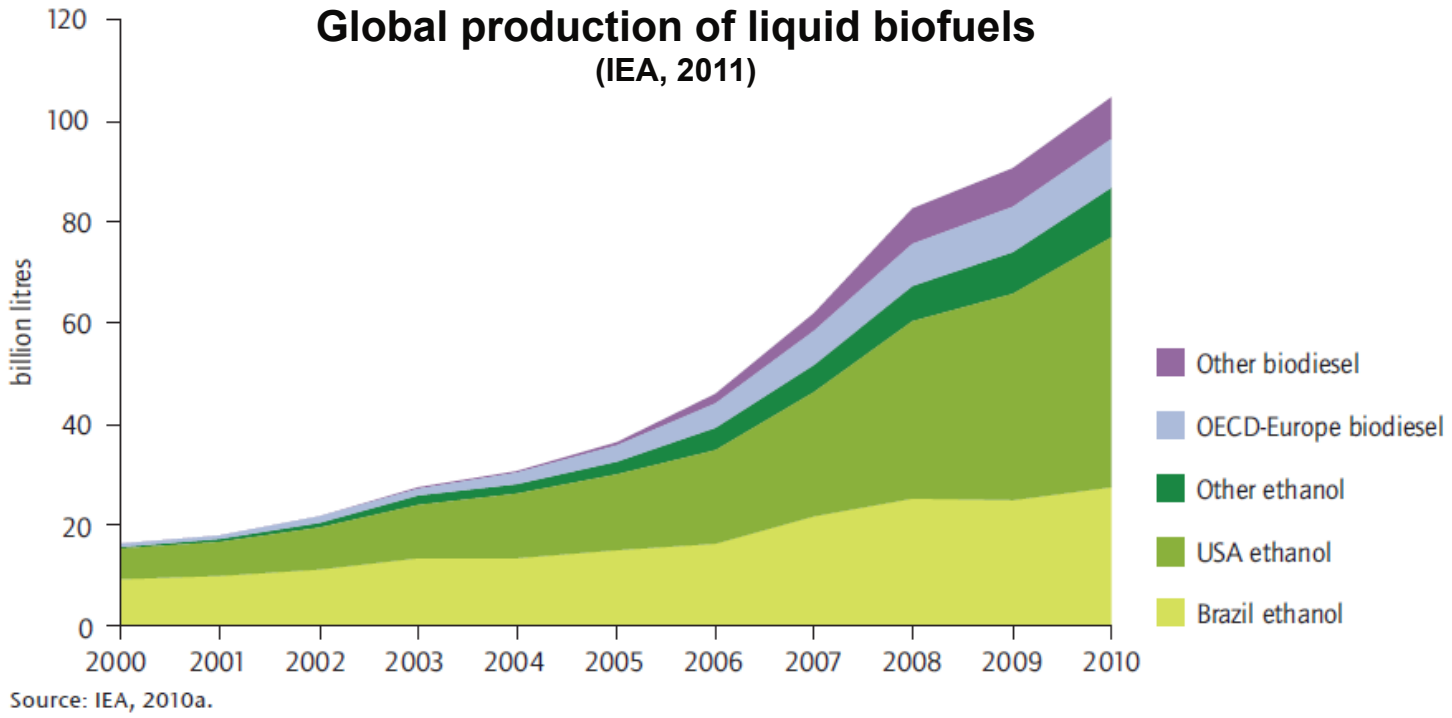
- ✓ ***Context: bioenergy is relevant abroad and in Brazil***
- ✓ ***The evolution of Brazilian bioenergy agro-industry***
- ✓ ***Sustainability of sugarcane bioenergy: new aspects***
- ✓ ***Current challenges on competitiveness***
- ✓ ***Final comments***

Bioenergy in the global scenario

More and more, the main drivers towards a global energy transition:

- ✓ ***concerns on oil dependence and energy costs;***
- ✓ ***global and local environmental problems,***
- ✓ ***opportunity for economic activation of agro-industrial sector,***

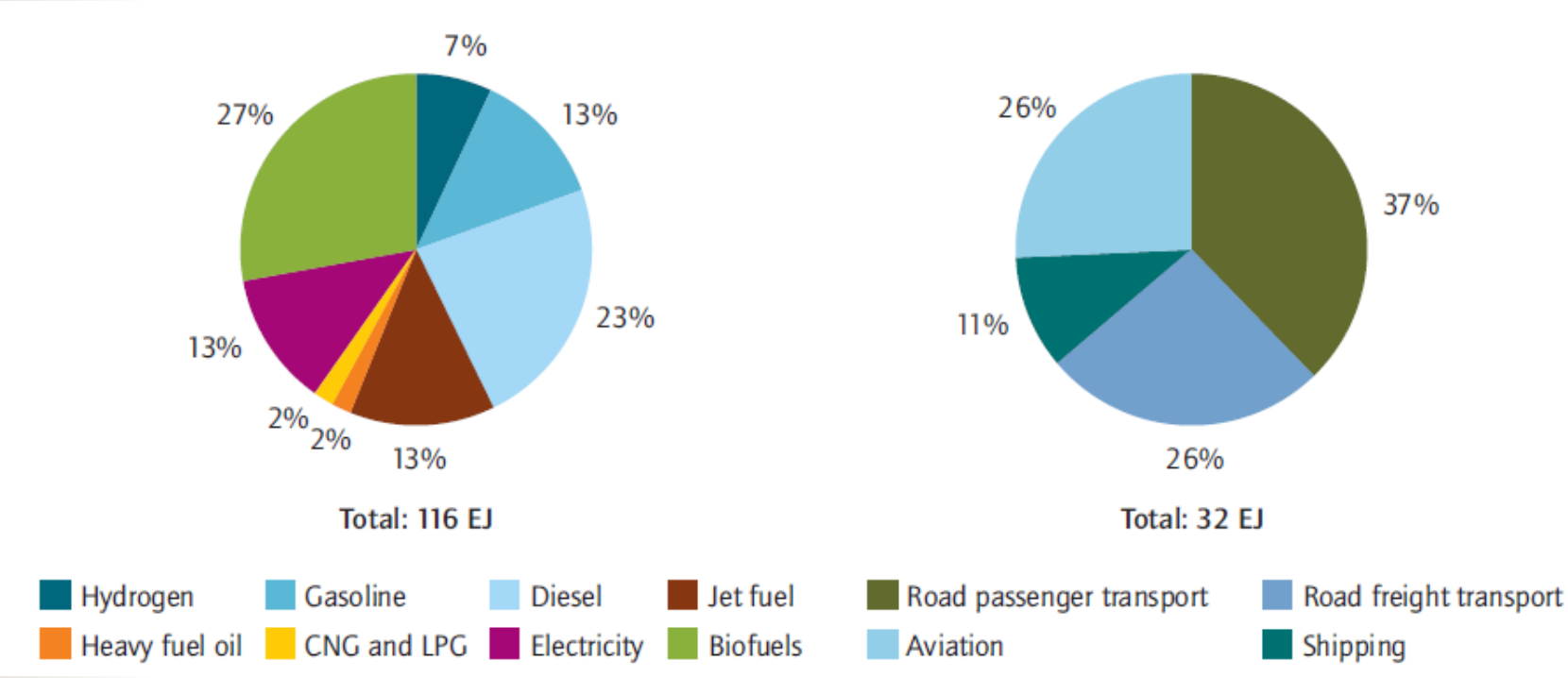
are reinforcing and fostering biofuels production and use abroad…



Bioenergy in the global scenario

…as well as biofuel demand forecasts are indicating a huge market for bioenergy in the next decades.

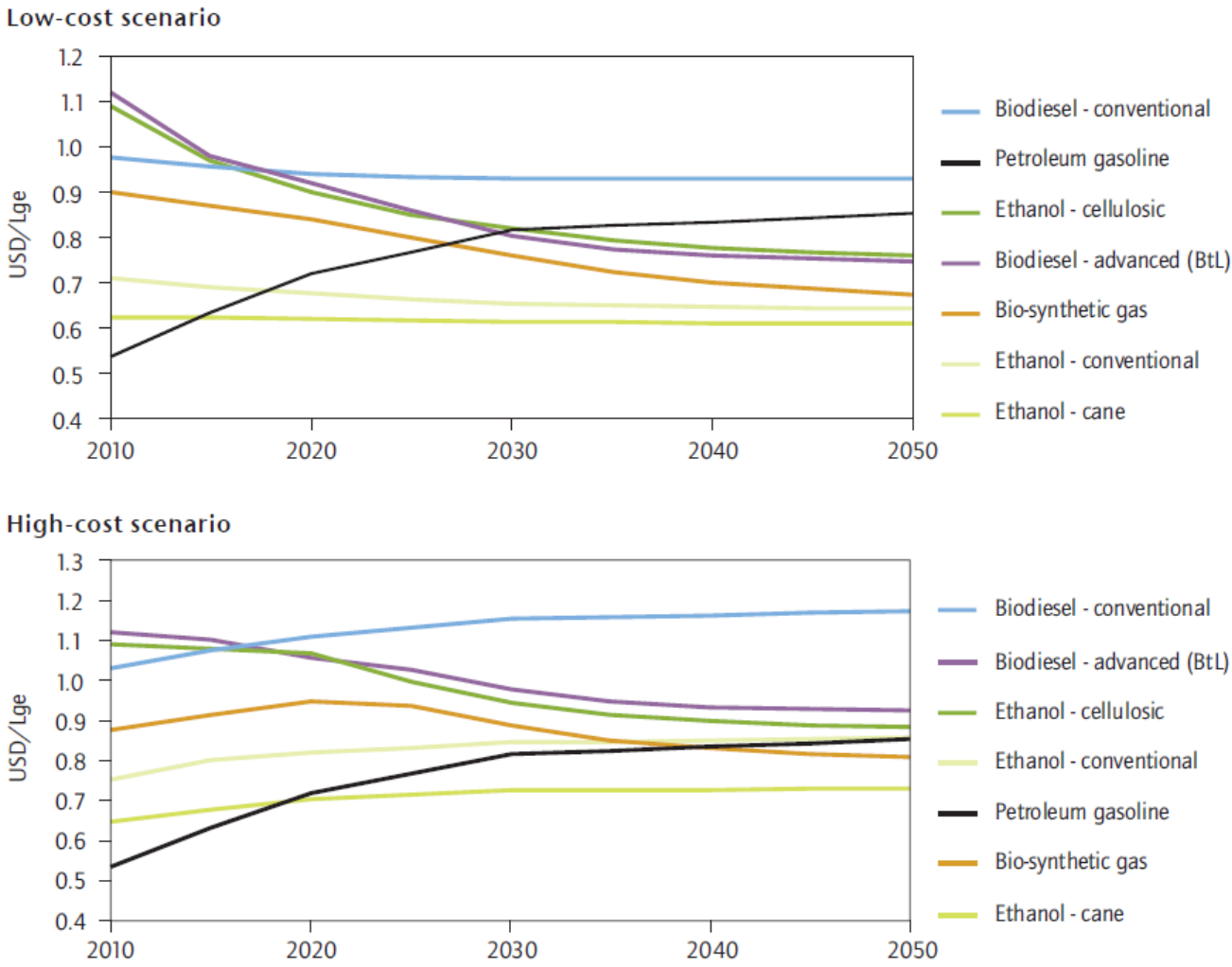
Global energy use in the transport sector and use of biofuels in different transport modes in 2050
(BLUE Map Scenario, IEA, 2011)



Bioenergy from sugarcane is competitive

Among several types of biofuels, ethanol from sugarcane presents lower cost and excellent environmental outcome.

Price forecast for automotive biofuels (IEA, 2011)



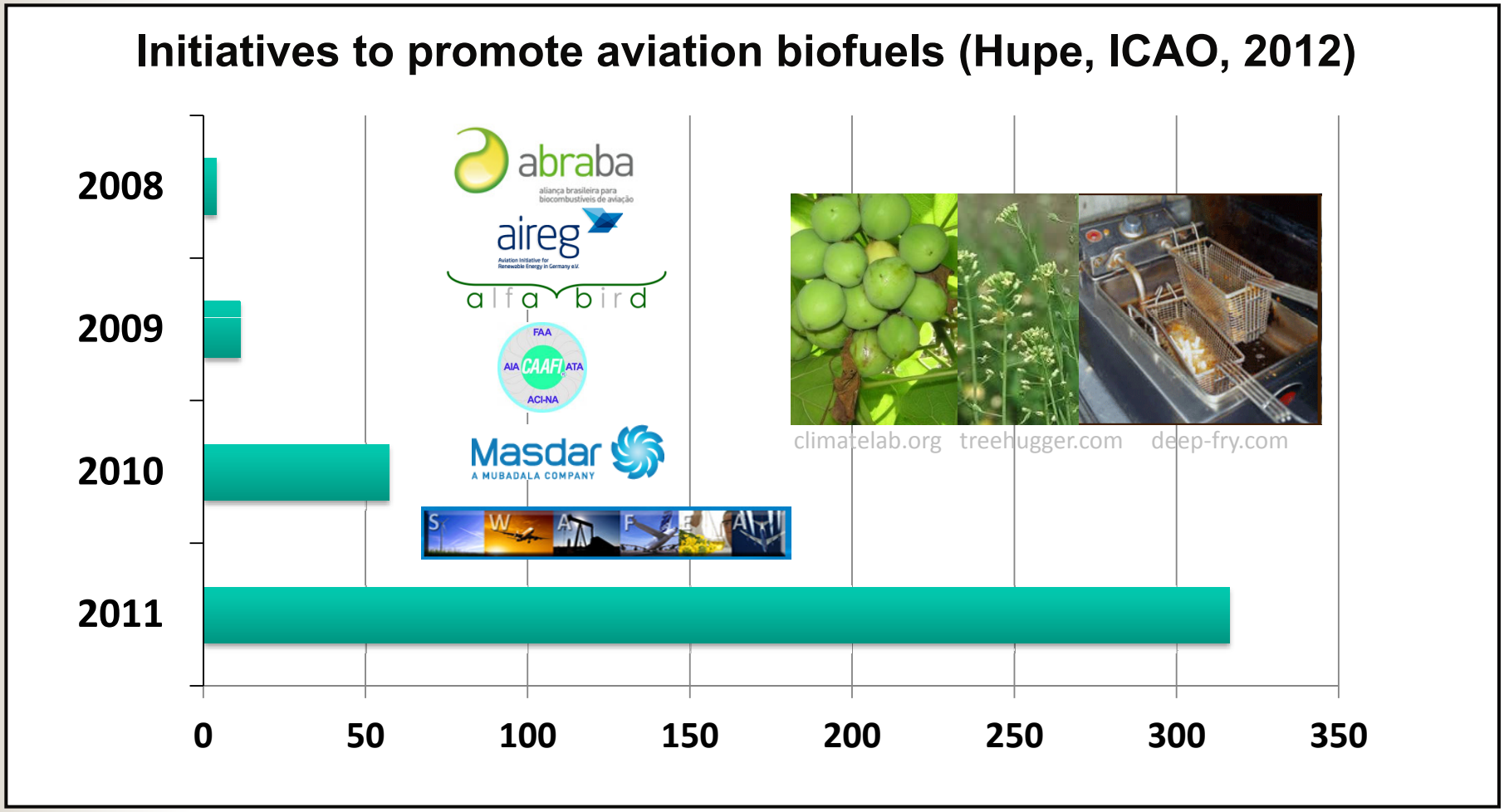
New markets for biofuels

Besides ethanol and biodiesel, recently a third kind of biofuel appeared, for aviation application, arising globally a great interest and bringing new challenges to be sustainably produced.

Drop-in biofuels
are biofuels that can be mixed with conventional jet fuel, use the same supply infrastructure and do not require adaptation of aircraft or engines, attending the ASTM D4054 specification.

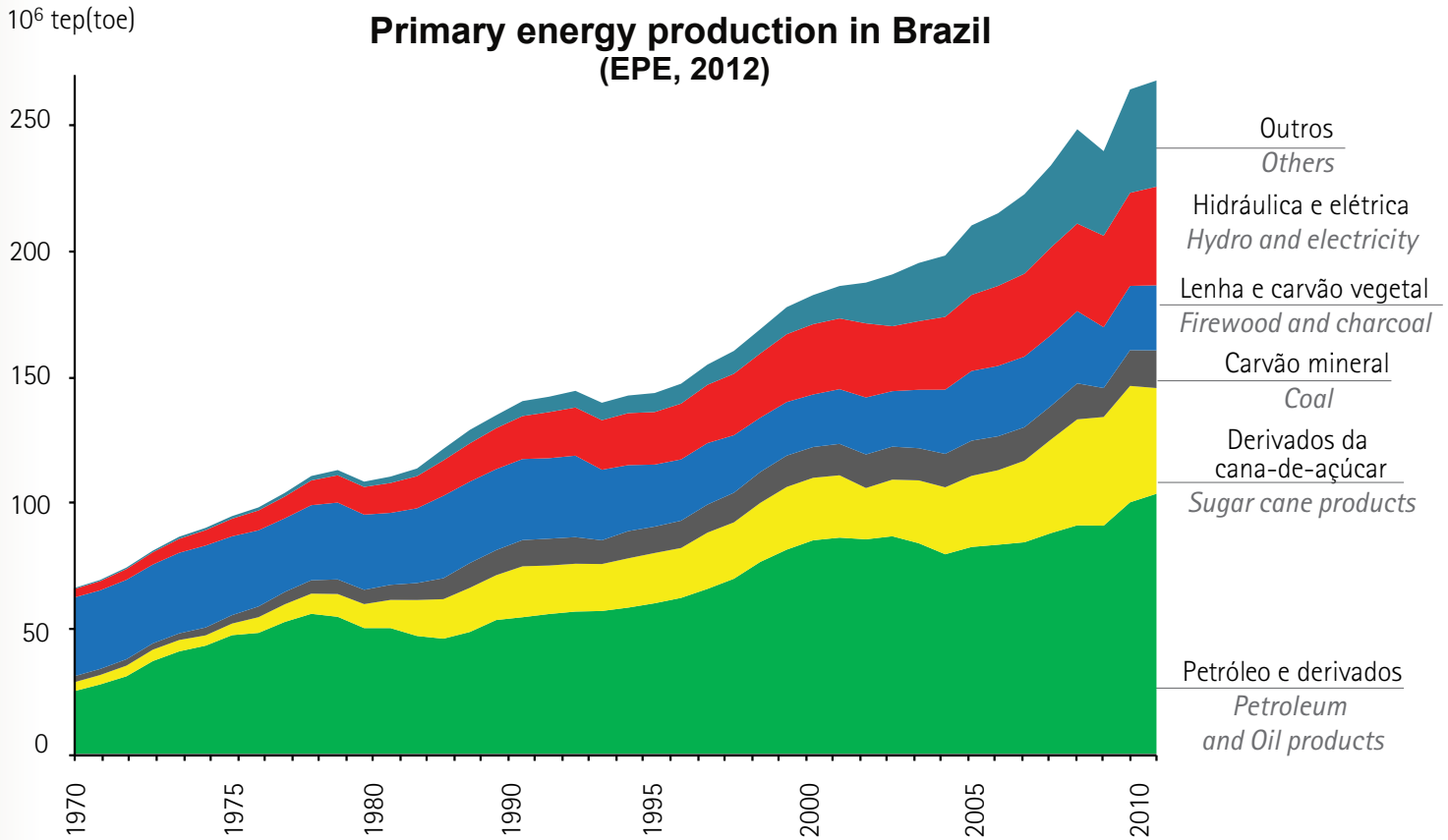
New markets for biofuels

A growing number of airlines are demonstrating the use of biofuels, some of them are using biofuels in regular commercial flights.



Bioenergy in Brazil

Biofuels always accounted for a significant share of Brazilian energy matrix. Currently, sugar cane, wood and several waste biomass mean about 1/3 of total domestic energy consumption.



The sugarcane energy in Brazil

Sugarcane energy products (ethanol and electricity) demand in Brazil is equivalent to about 800 thousand barrels of oil per day.

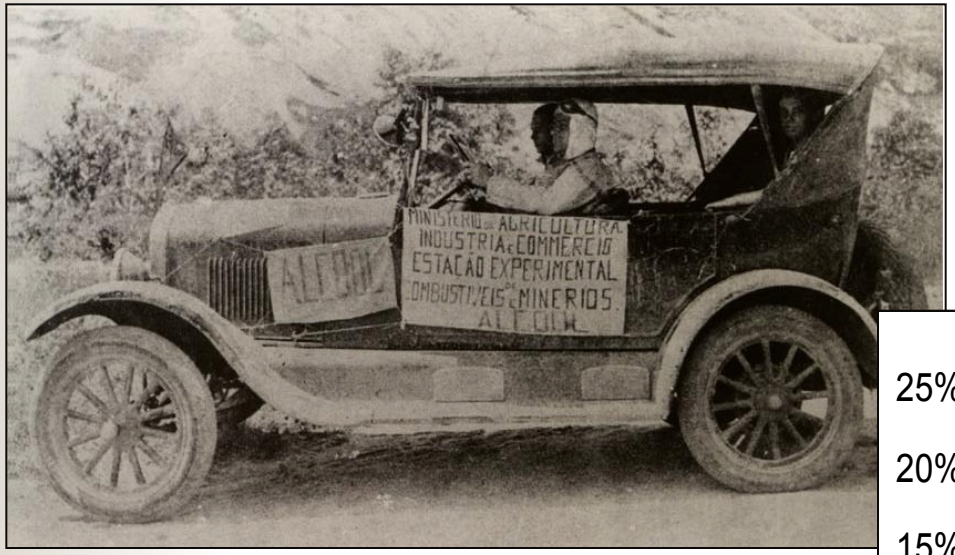
More than 32 million Brazilian cars run using ethanol, either pure (E100) or blended with gasoline (E25-E18).

The area occupied with sugarcane plantation for energy represents a small share of arable land (<1%), with reduced impacts on biodiversity and the production of other agricultural products.

Typical sugarcane mill in the Brazilian Center South region
(BNDES, 2009)

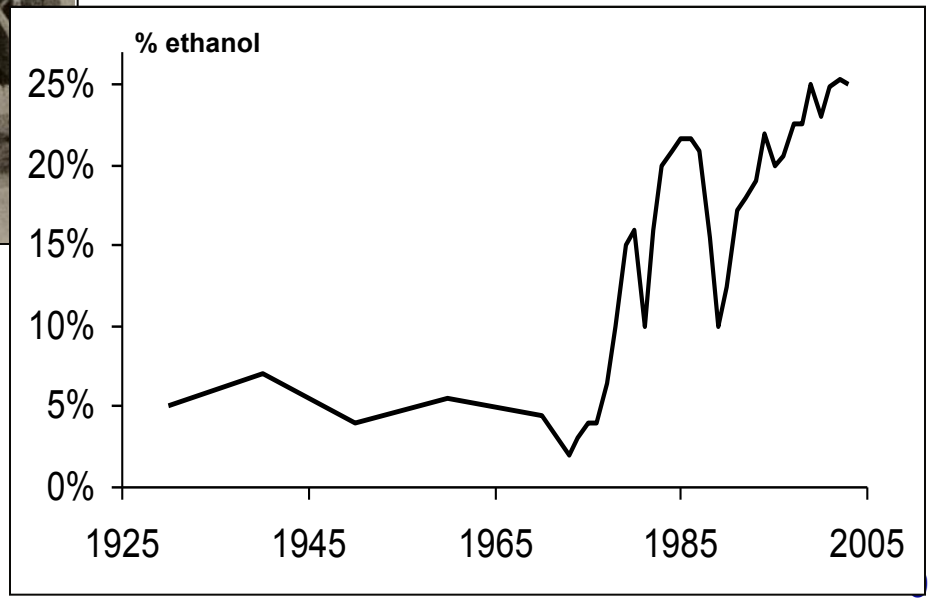
Ethanol use: the initial steps

Gasoline blended with ethanol has been a mandatory practice in Brazil since 1931 (minimum E5, average E7.5), reinforced after the oil crisis during the seventies, when the use of high blends (E25) in all gasoline motors and pure hydrous ethanol in dedicated motors was adopted.



Ford Model T adapted for pure ethanol, used for public demonstrations in the 20's

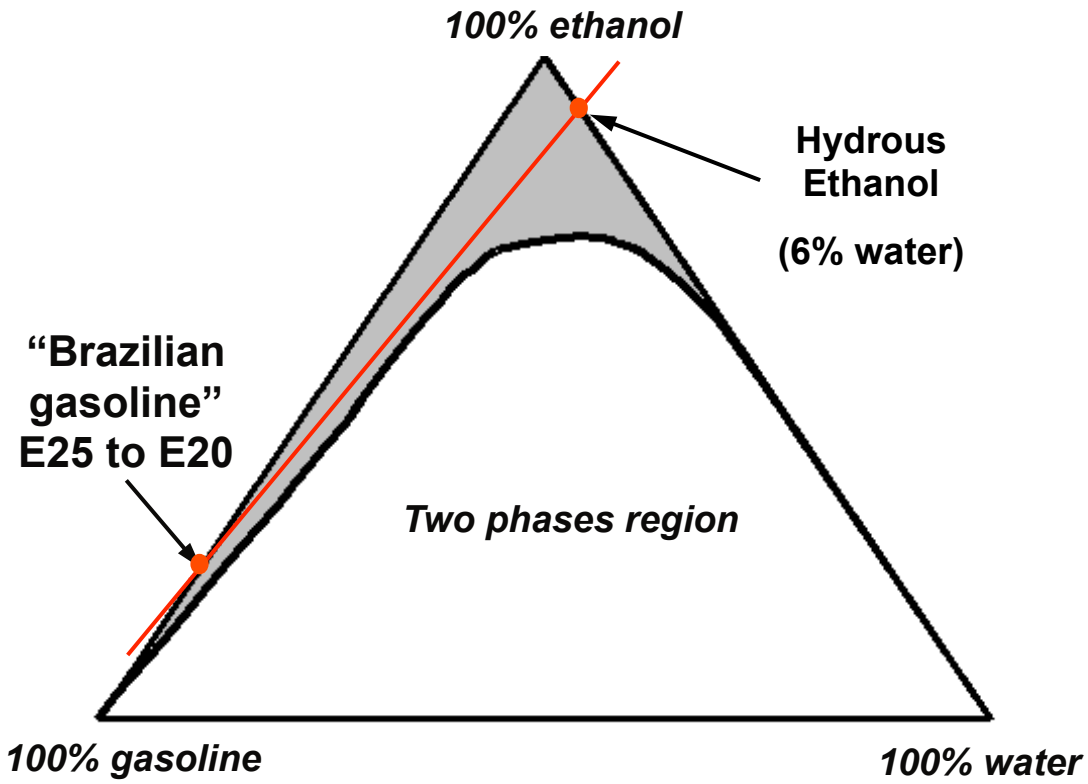
(INT, 2006)



Ethanol content in the Brazilian gasoline
(BNDES, 2008)

The ethanol evolution: flex-fuel motors

Vehicles with motors able to use any blend of pure hydrous ethanol (E100) and gasoline (E25), presenting good performance and accomplishing environmental requirements, were introduced successfully in the Brazilian market and today represents around 90% of new cars in the light vehicles fleet.



Ternary diagram ethanol/gasoline/water
(CTC, 2004)

New frontiers for ethanol use

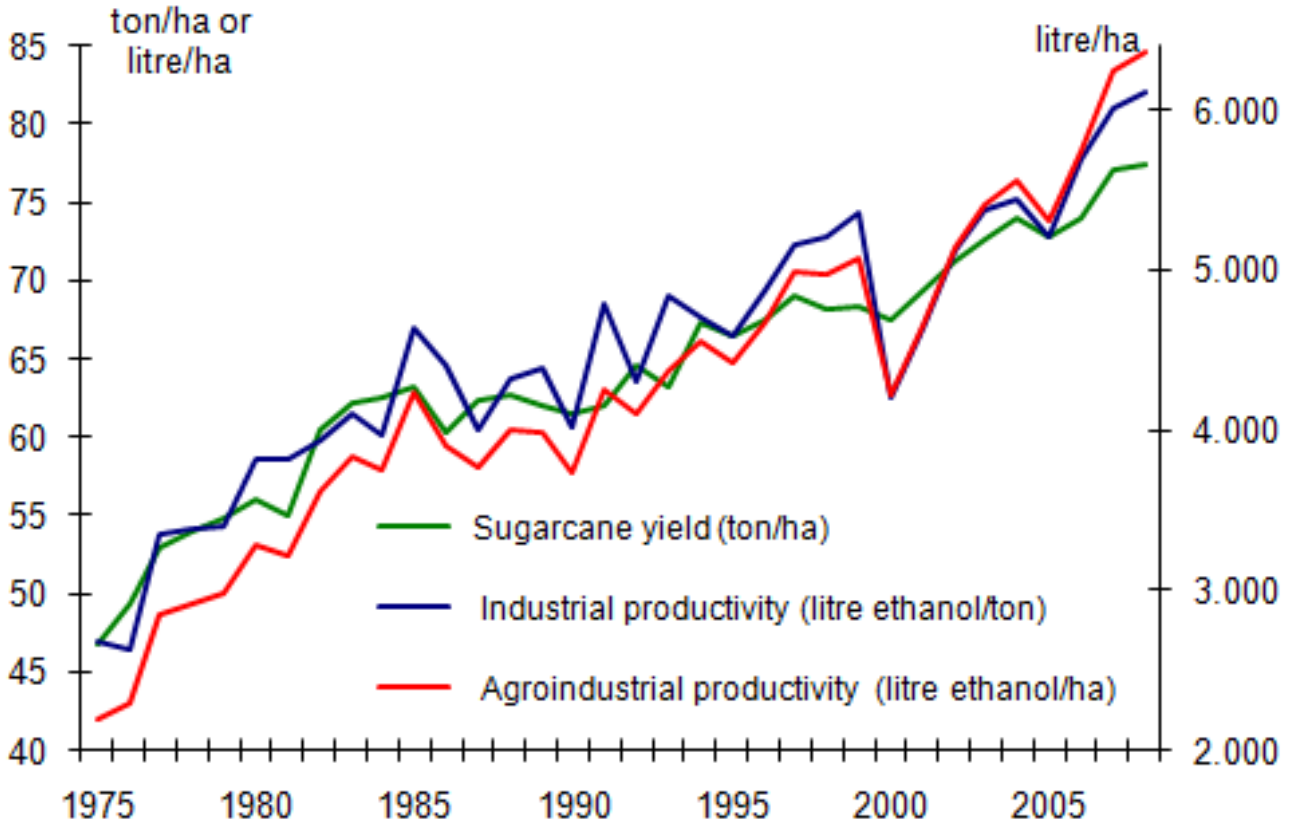
Besides the regular use as pure hydrous ethanol and in blend with gasoline, new interesting opportunities are opening new and promising markets for bioethanol.

Airplane regularly produced to use pure hydrous ethanol
(EMBRAER, 2008)

Bus with Diesel engine able to use hydrous ethanol
(BEST, 20099)

The ethanol evolution: productivity

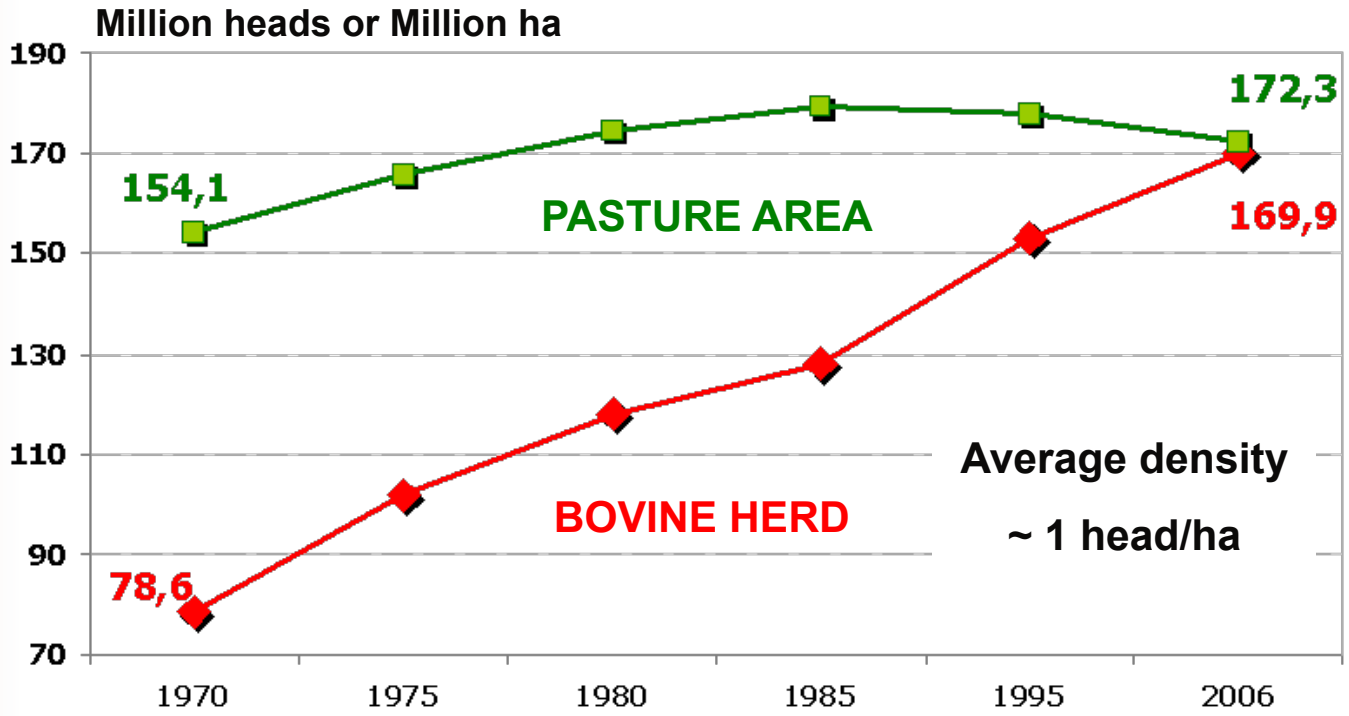
In the last three decades many improvements has been introduced in ethanol production, multiplying the total productivity by 2.6, due to agronomic and industrial gains.



(CONAB/MAPA, 2010)

The ethanol evolution: productivity

To reduce the competition for natural resources, efficiency is crucial at any level. For animal protein this aspect is more relevant yet.



In Brazil, better practices in calf breeding can liberated about 75 M ha.

(FGV, IBGE, 2008)

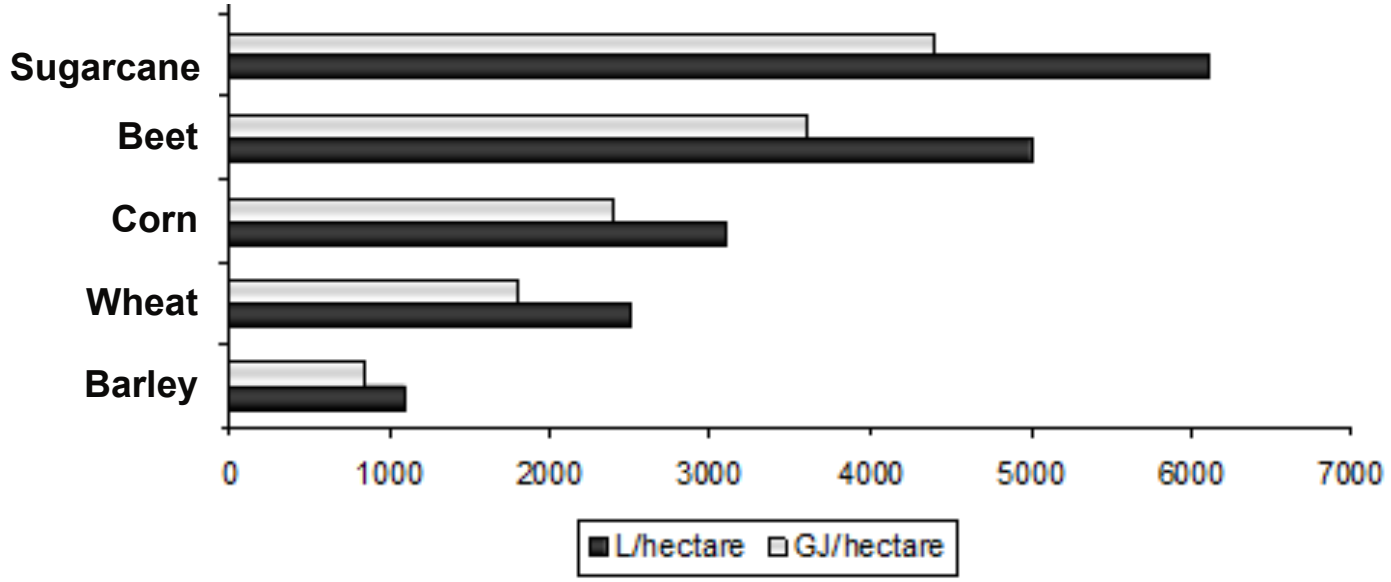
Sustainability: an imperative for bioenergy

As defined by the Brundtland Commission in the 1980s, it is expected that sustainable systems be capable of «meeting the needs of the present without compromising the ability of future generations to meet their own needs», while promoting social and ecological equilibrium as well as the needs of the poor (United Nations,1987).

In our context, sustainability can be defined as the possibility of bioenergy systems systems maintain their production over the long term, without overt depletion of the resources that originally gave rise to them, such as biodiversity, soil fertility, and water resources, keeping their economic competitiveness and social acceptance.

Sustainability: the energy balance role

Among several sustainability indicators, the energy output/input ratio is one of high importance, pointing out also the long term economic feasibility and offering the basic data for the Life Cycle Analysis.



Agroindustrial productivity of different feedstock in ethanol production (adapted from Royal Society, 2008)

Ethanol: a very positive energy balance

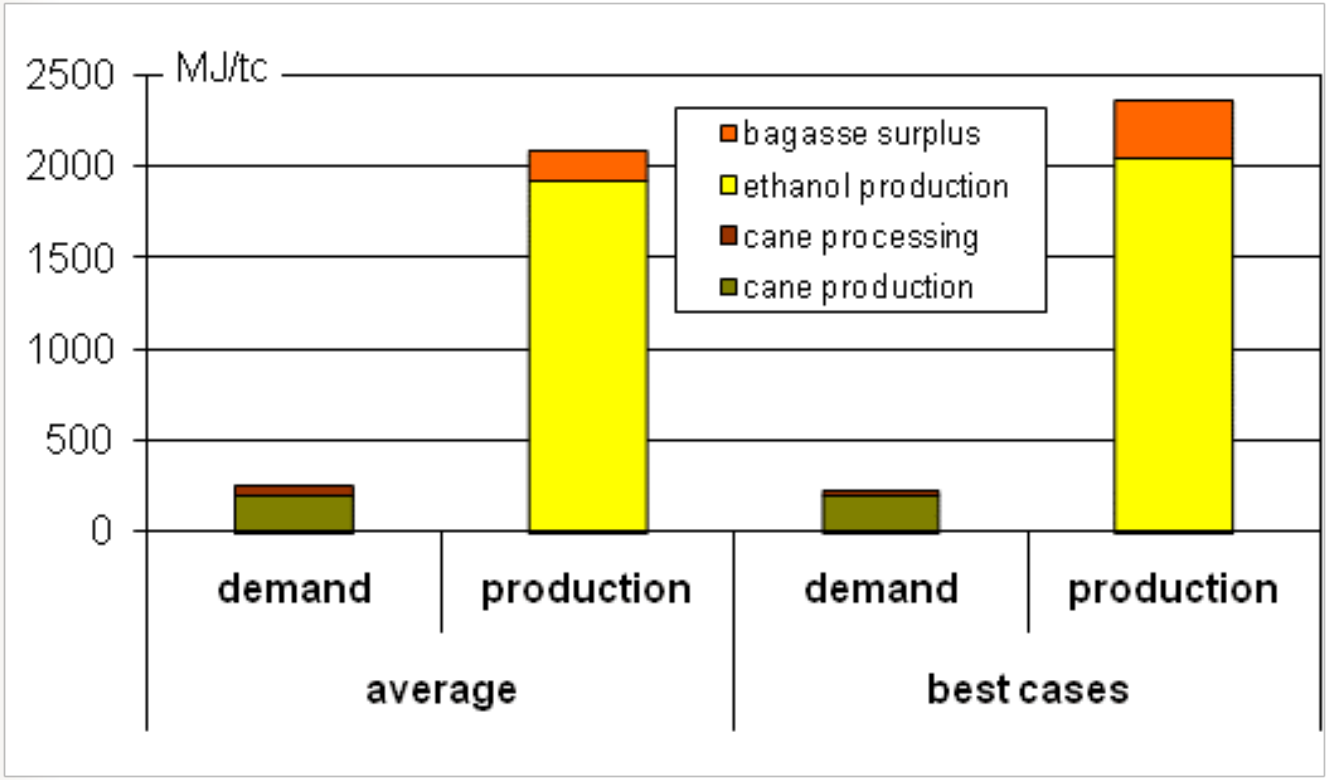
One outstanding feature of sugarcane ethanol is its excellent surplus in solar energy conversion to chemical energy and consequently fuel energy.

Operation	Energy requirements or production (MJ/ tonne of processed cane)	
	average	best values
Sugar cane production	**202**	**192**
Agricultural operations	38	38
Cane transportation	43	36
Fertilizers	66	63
Lime, herbicides	19	19
Seeds	6	6
Equipment	29	29
Ethanol production	**49**	**40**
Electricity	0	0
Chemicals and lubricants	6	6
Buildings	12	9
Equipment	31	24
Total energy input	**251**	**232**
Energy output	**2089**	**2367**
Ethanol	1921	2051
Bagasse surplus	169	316
Net energy balance (out/in)	**8,3**	**10,2**

(Macedo et al., 2006)

Ethanol: a very positive energy balance

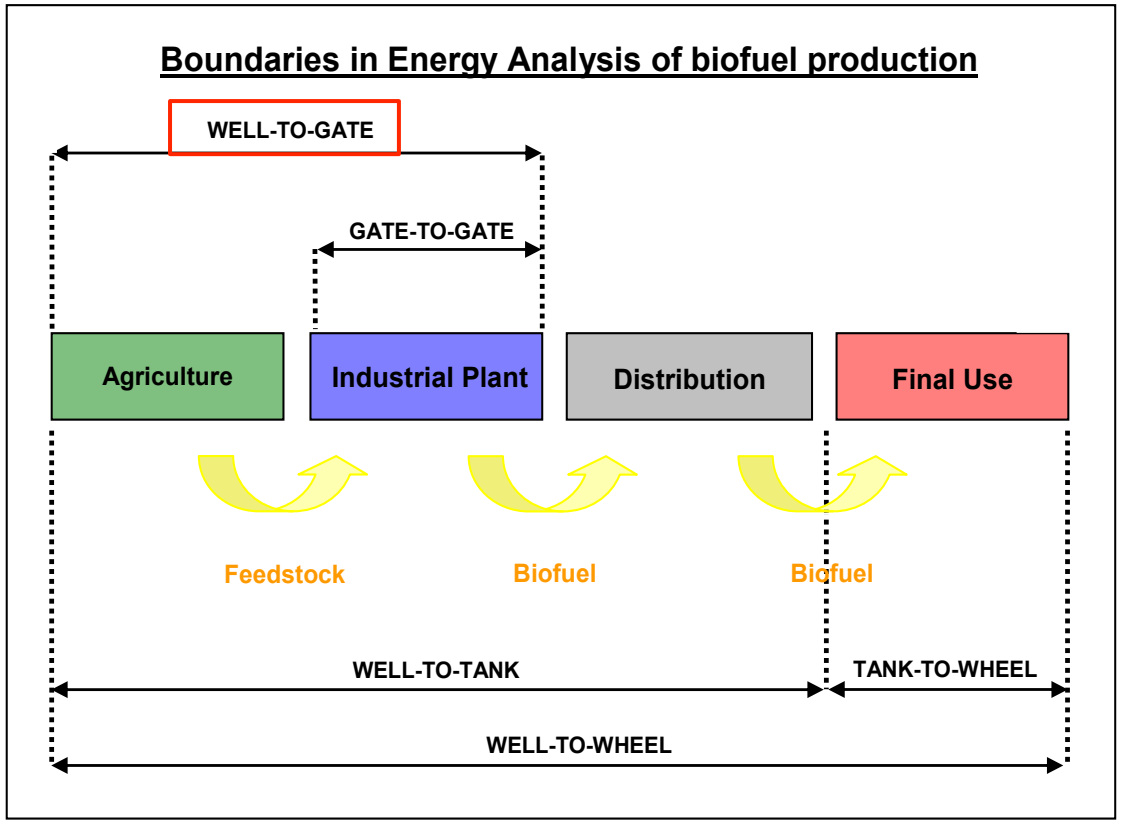
Currently, any other liquid biofuel route is able to collect and convert solar energy with this performance.



(Macedo et al., 2006)

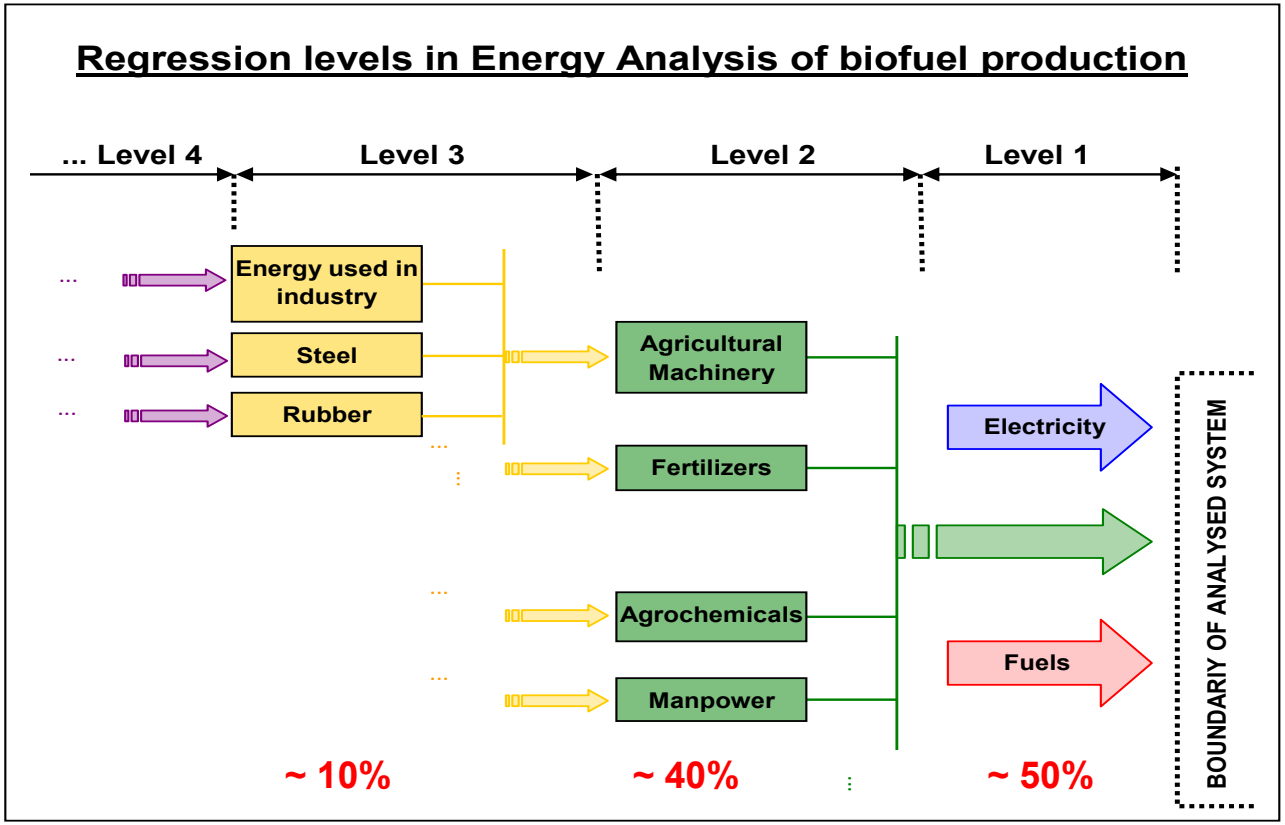
Exploring the energy balance of ethanol

The assessment of energy flows in a productive system (Energy Analysis), was developed during the 70's and expanded further to the Life Cycle Analysis (standardized under ISO 14000 framework).



Exploring the energy balance of ethanol

Some aspects still can be consolidate: a) the boundaries of the evaluated systems, b) the energy coefficient for inputs and outputs , c) the allocation method to be used with by-products and d) the formulation of indicators.



Exploring the energy balance of ethanol

Energy flows for a representative ethanol mill of the Brazilian Center-South region were studied, gathering direct information in actual mills and using data from other authors.

Inputs and energy demand in sugarcane production.

Parameters	without vinasse use			using vinasse		
	Input	Energy input [MJ/t_{cane}]		Input	Energy input [MJ/t_{cane}]	
Nitrogen [kg/ha]	68.0	45.2	(31.1%)	50.0	33.2	(23.2%)
Phosphorous (P_2O_5) [kg/ha]	36.8	4.1	(2.8%)	8.3	0.9	(0.6%)
Potassium (K_2O) [kg/ha]	96.2	8.5	(5.9%)	13.3	1.2	(0.8%)
Lime [kg/ha]	960.0	11.3	(7.8%)	958.3	11.3	(7.9%)
Herbicides [kg/ha]	2.2	8.0	(5.5%)	2.2	8.0	(5.6%)
Insecticides [kg/ha]	0.2	0.6	(0.4%)	0.2	0.6	(0.4%)
Seed [kg/ha]	-	4.4	(3.0%)	-	4.3	(3.0%)
Equipment [kg/ha]	54.2	5.0	(3.4%)	70.7	6.6	(4.6%)
Diesel [L/ha]	100.6	56.6	(39.0%)	125.6	75.8	(52.9%)
Labor [h/ton.H]	0.7	1.5	(1.0%)	0.7	1.5	(1.0%)
Total	-	145.2	(100%)	-	143.4	(100%)

Exploring the energy balance of ethanol

For the industrial process, it was considered a plant for a daily production of 120,000 m^3 of ethanol, crushing a typical cane (14.3%Pol, 12.8%Fiber). More information about assumptions done and the criteria adopted in selecting energy coefficients is available in the paper. The mill is assumed as self-sufficient in energy.

Inputs and energy demand in the industrial stage of ethanol production.

Parameters	Input	Energy input [MJ/$t_{ethanol}$]	
Chemicals inputs	-	92.0	(21.5%)
Eletricity [MJ]	0.0	0.0	(0.0%)
Steam [kg]	0.0	0.0	(0.0%)
Equipments [ton]	1,323.0	323.6	(75.4%)
Buildings [m²]	9,000.0	13.3	(3.1%)
Total	-	428.9	(100%)

Exploring the energy balance of ethanol

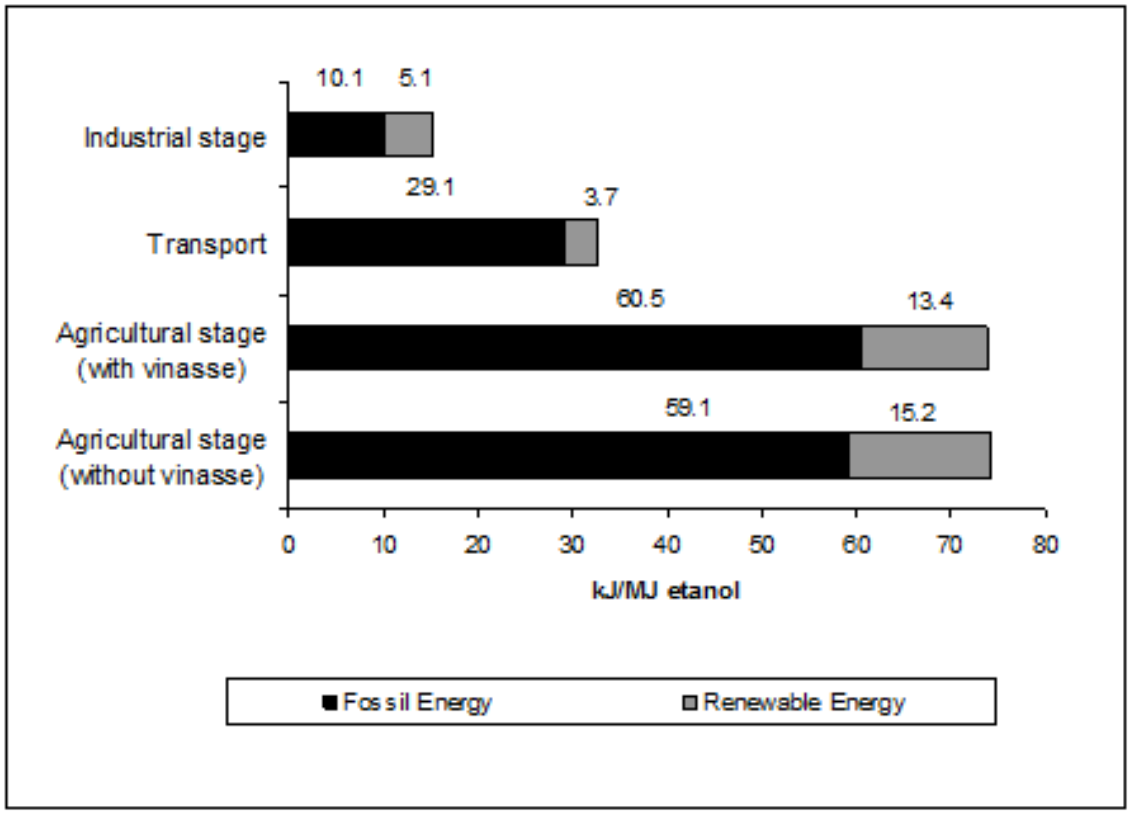
In this representative scenario, it was assumed an average productivity of 86.5 liters of ethanol/ton of cane. The bagasse is used in conventional cogeneration schemes (live steam at 22 bar), allowing surpluses production of bagasse (11.2% of production) and electricity (15 to 150 kWh/ton of cane).

Outputs in the industrial stage of ethanol production.

By-products	Net prodution	Energy output [$kJ/MJ_{ethanol}$]
Ethanol [kg/t_{cane}]	69.2	1,000.0
Bagasse [kg/t_{cane}]	31.4	120.4
Eletricity [MJ/t_{cane}]	43.2	22.1

Energy indicators of ethanol production

Sugarcane production is the most important stage in terms of energy demand, followed by the raw material transportation to the mill. In agricultural activities about 80% of energy consumed come from fossil sources.



Energy demand in ethanol production

Energy indicators of ethanol production

In order to explore the sensitivity of energy performance indicators of ethanol from sugarcane production, some parameters were evaluated using the previous data.

Energy output/input ratios: effect of regression levels

Regression levels	Formulation		Total Energy	Fossil Energy
Levels 1+2 (I_{NR2})	$I_{NR2} = \frac{E_{Biof.} + E_{By-prod.}}{E_{NR1} + E_{NR2}}$	E_{Biof}: Embodied energy in biofuel $E_{By\text{-}prod.}$: Embodied energy in by-products E_{NR1}: Consumed energy in regression level 1 E_{NR2}: Consumed energy in regression level 2	10.88	13.17
Levels 1+2+3 (I_{NR3})	$I_{NR3} = \frac{E_{Biof.} + E_{By-prod.}}{E_{NR1} + E_{NR2} + E_{NR3}}$	E_{NR3}: Consumed energy in regression level 3	9.35	11.88

Energy indicators of ethanol production

Energy output/input ratios: effect of boundary of analysis

Boundary of system	Formulation		Total Energy	Fossil Energy
Agricultural (I_{FRa})	$I_{FRa} = \frac{E_{Biomass}}{E_{Agr}}$	$E_{Biomass}$: Embodied energy in biomass [MJ/kg]; E_{Agr}: Consumed energy in agricultural stage	137.8	174.2
Solar radiation (I_{FRs})	$I_{FRs} = \frac{E_{Biomass}}{E_{Agri} + E_{Sun}}$	E_{Sun}: Input of energy by solar radiation, for an average rate of 18.0 MJradiation/m².day	0.026 (2.6%)	
Industrial (I_{FRi})	$I_{F\,\mathrm{Re}} = \frac{E_{Raw-material} + E_{By-prod.}}{E_{Biomass} + E_{Industry}}$	$E_{Raw-material}$: Embodied energy in raw-material; $E_{By-prod.}$: Embodied energy in by-products; $E_{Industry}$: Consumed energy in conversion stage	0.11[b]	0.11

Energy output/input ratios: effect of indicator definition

Indicator	Formulation		Total Energy	Fossil Energy
Net flow indicator (I_L)	$I_L = \frac{E_{Output} - E_{Input}}{E_{Input}}$	E_{Output}: Produced energy in system; E_{Input}: Consumed energy in system	8.34	10.90

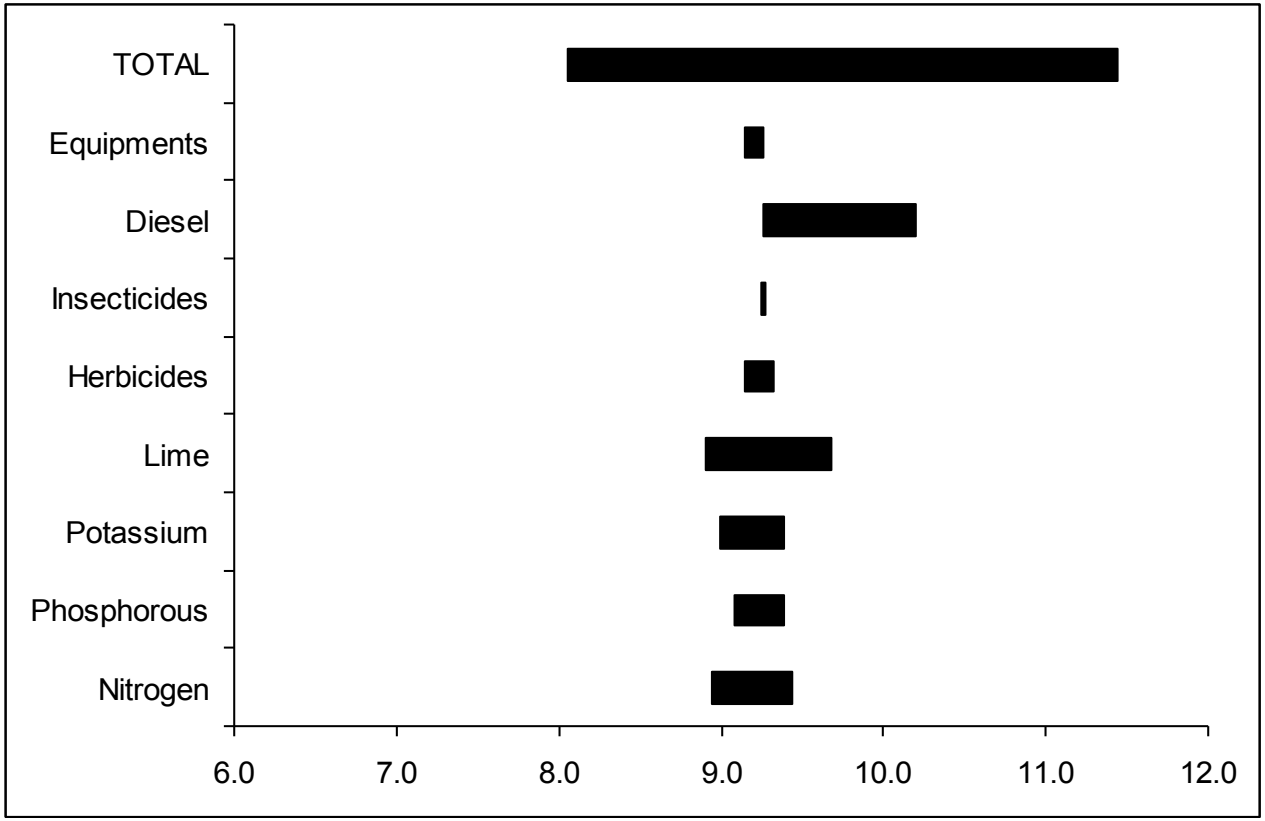
Energy indicators of ethanol production

Energy output/input ratios: effect of allocation method (among by-products)

Allocation method	Formulation		Total Energy	Fossil Energy
Only ethanol (I_{An})	$I_{An} = \frac{E_{Biof.}}{E_{NR3}}$	E_{Biof}: Embodied energy in biofuel E_{NR3}: Consumed energy in regression level 3	8.18	10.40
Mass (I_{Am})	$I_{Am} = \frac{E_{Biof.}}{E_{mass} \cdot E_{NR3}}$	E_{mass}: Allocated energy in function of mass	11.89	15.11
Energy (I_{Ae})	$I_{Ae} = \frac{E_{Biocomb.}}{E_{energia} \cdot E_{NR3}}$	E_{energy}: Allocated energy in function of energy	8.44	
Monetary value (I_{Av})	$I_{Avm} = \frac{E_{Biof.}}{E_{value} \cdot E_{NR3}}$	E_{value}: Allocated energy in function of monetary value	8.43	10.51

Energy indicators of ethanol production

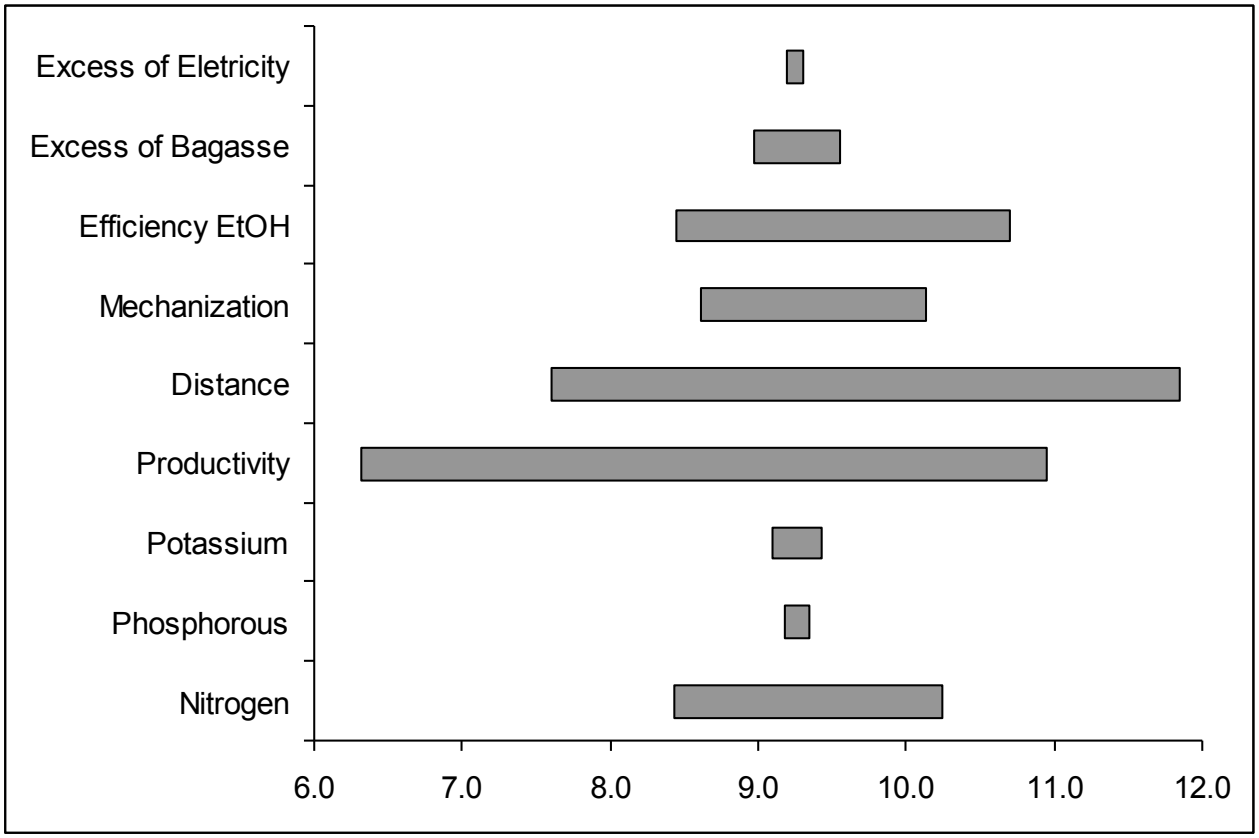
Energy output/input ratios: effect of input energy coefficients



Variation of Indicator I_{AE} (for Total Energy) for different values of energy demand of inputs available in literature

Energy indicators of ethanol production

Energy output/input ratios: effect of production parameters

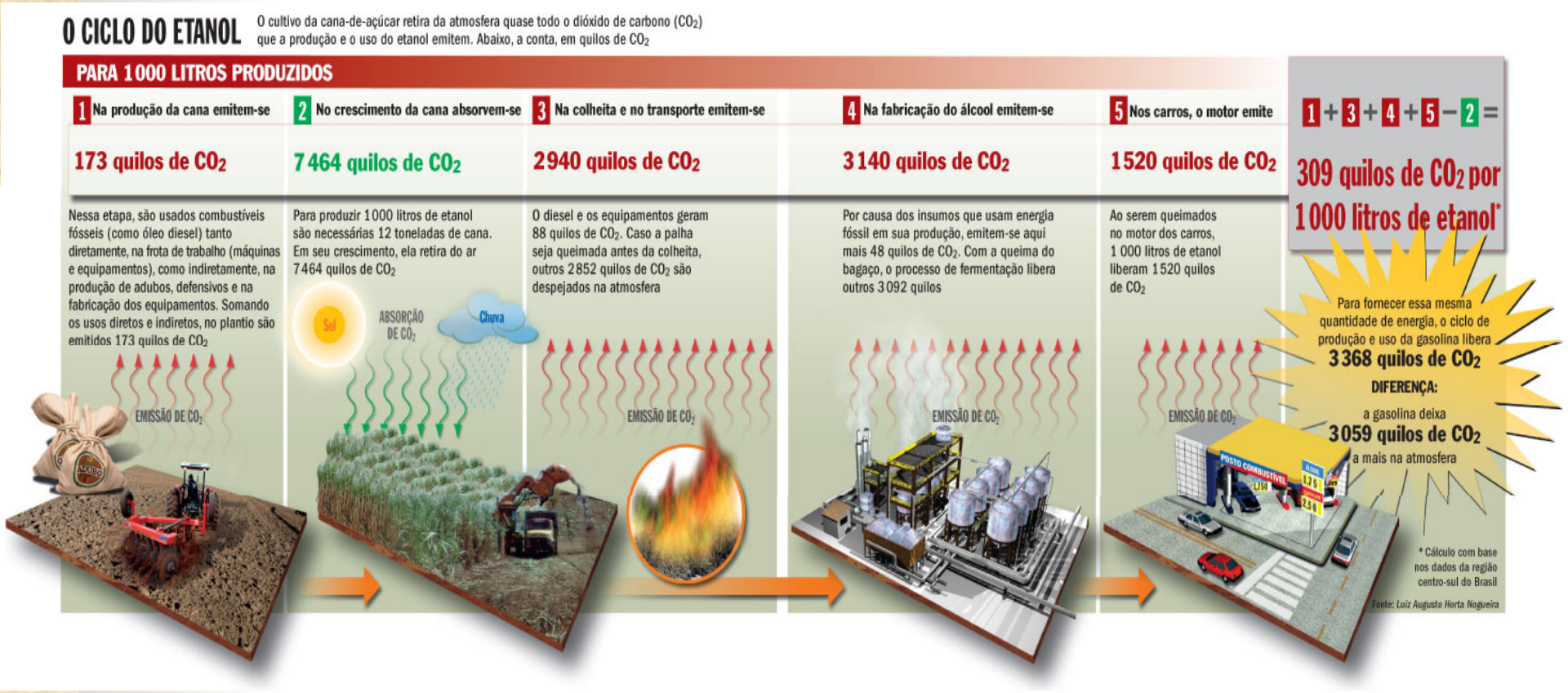


Variation of Indicator I_{AE} (for Total Energy) for different production conditions (*ceteris paribus* an base case)

Sustainability: the CO_2 emission balance

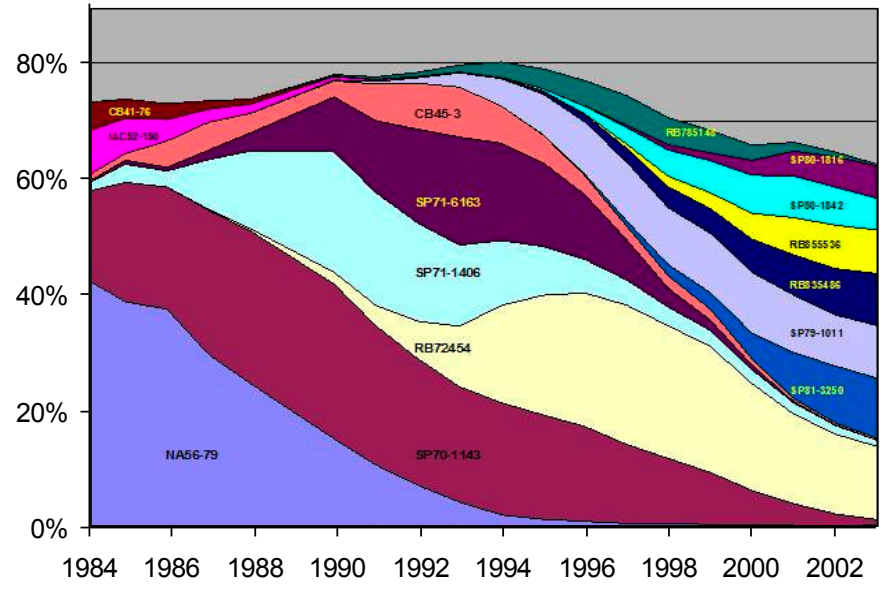
Summary balance of CO_2 emission in the ethanol production and use in the Brazilian Center-South (kg CO_2/1,000 liters of ethanol)

Stage	Photosynthesis CO_2 absorption	Release of CO_2	
		Fossil	Photosynthesis
Planting		173	
Growth	7,464		
Harvest and transport		88	2,852
Ethanol manufacture		48	3,092
Ethanol use			1,520
Total	7,464	309	7,464



Sustainability: role of R&D

Innovation has been essential for ethanol development. In agronomic or industrial activities, in logistics or management, new techniques are frequently introduced, cutting costs, diversifying products and reducing environmental impacts of ethanol production.



Varietal diversification of sugarcane in Brazil
(Burnquist e Landell, 2005)

Biological control of sugarcane borer (*Diatraea saccharalis*) using a wasp (*Cotesia flavipes*)
(Bento, 2006)

Sugarcane production improvements

Sugarcane breeding
(CTC, 2009)

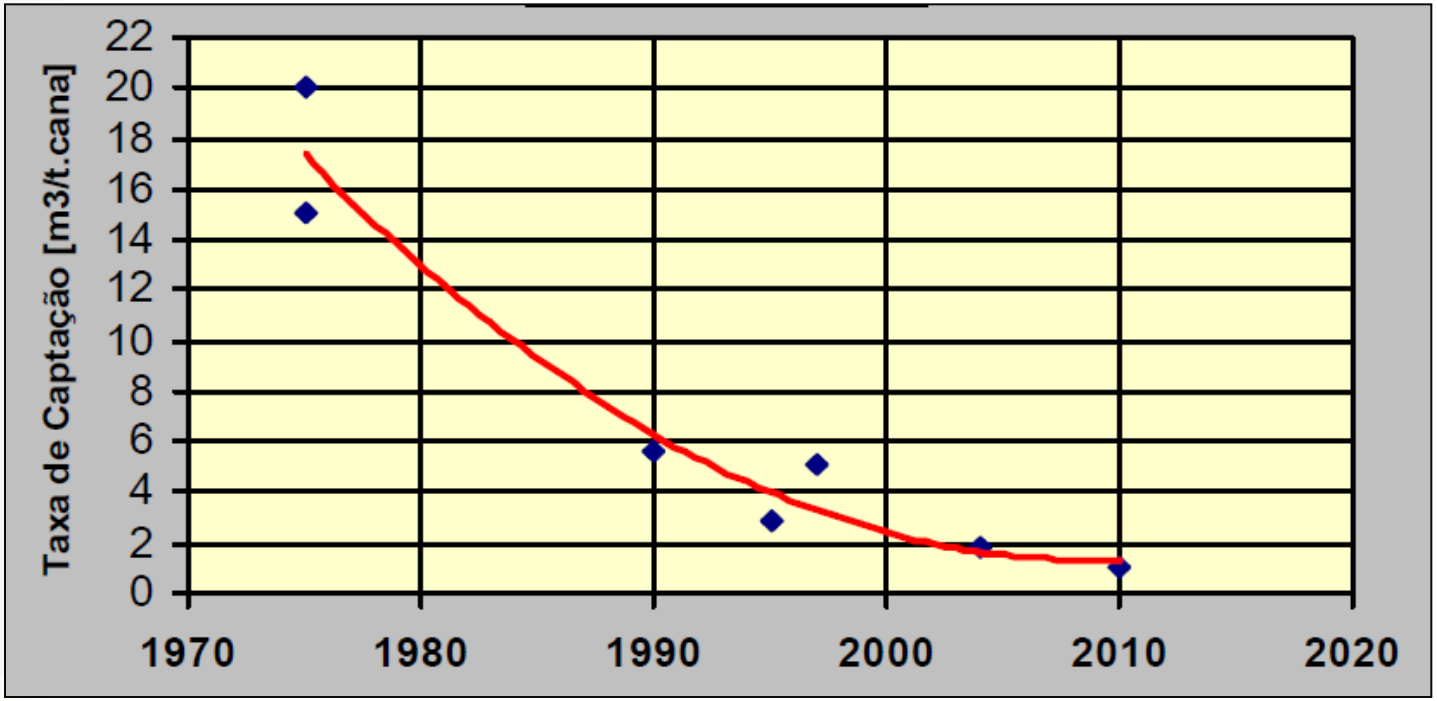
Use of vinasse as fertilizer
(UNICA, 2008)

Mechanized sugarcane harvesting
(UNICA, 2008)

Efficient feedstock logistics
(Scania, 2007)

Sustainability: water use

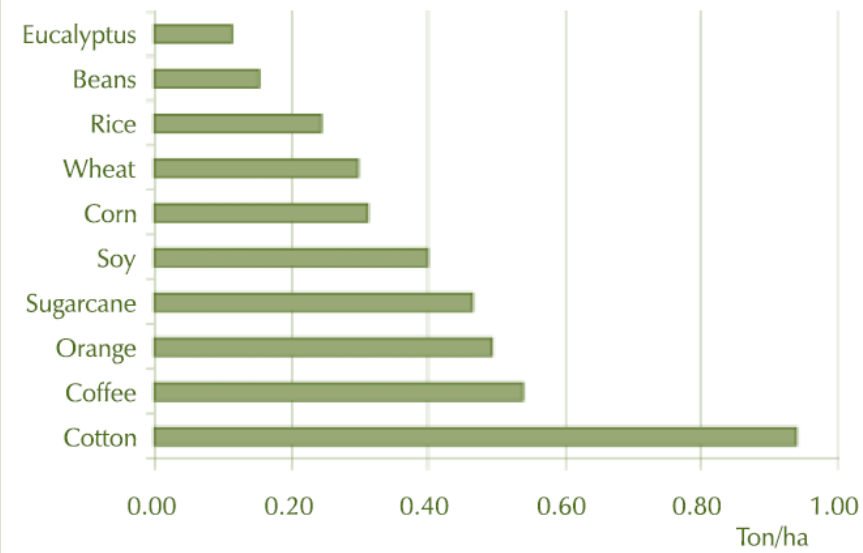
It is remarkable the reduction of water use in mills, consequence of recycling and reuse, pushed by legislation. Some decades ago, average mills used about 20 m^3/ton of cane, nowadays, such use is lower than 2.5 m^3/ton and for new mills, only plants using up to 1.0 m^3/ton are authorized.



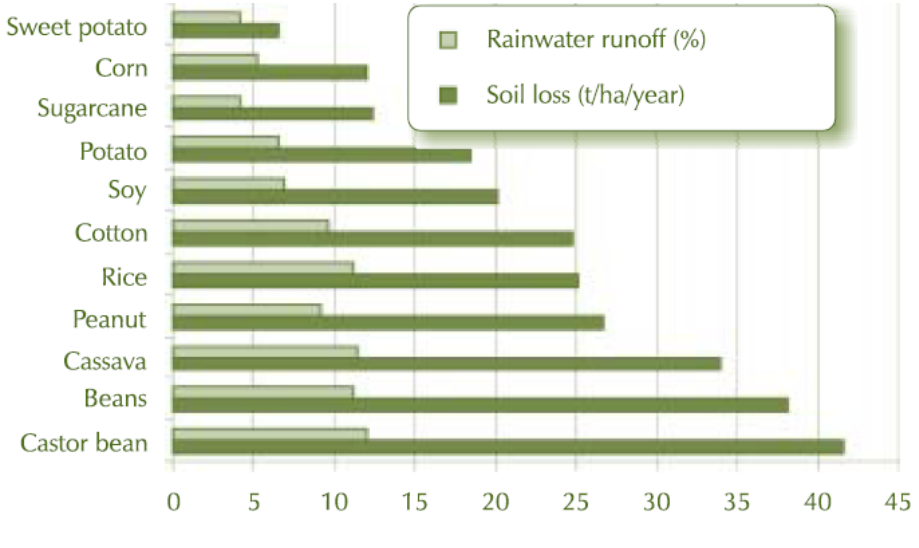
Evolution of water use in sugarcane mills in Brazil
(Elia Neto, 2010)

Sustainability: agrochemicals and erosion

The use of agrochemicals and soil losses in erosion in sugarcane production is reduced in comparison with other cultures.



Fertilizers consumption by the main crops in Brazil
(Donzelli, 2005)

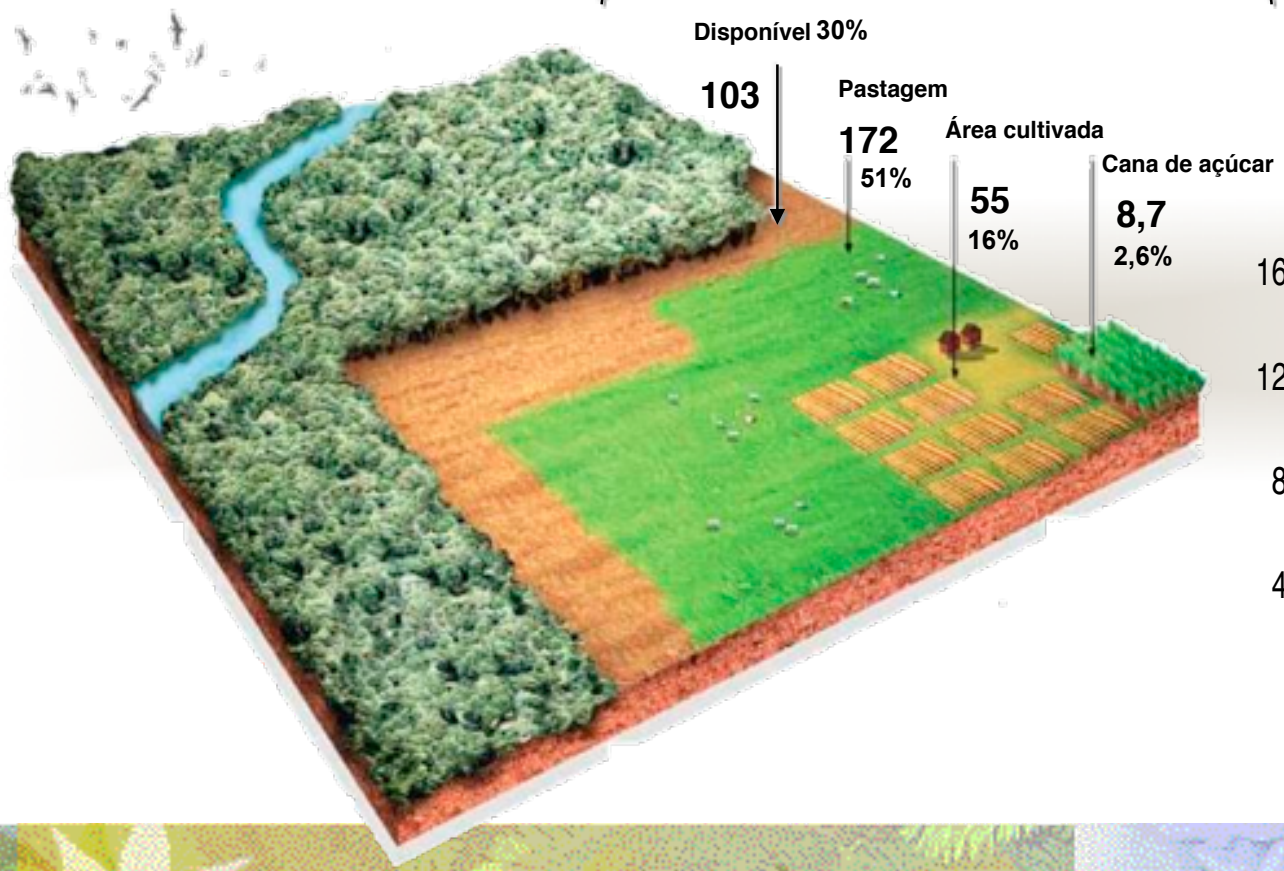


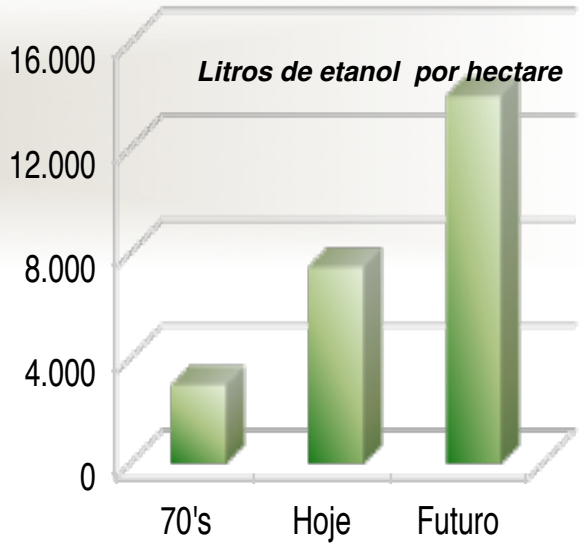
Soil loss and rainwater runoff for some Brazilian crops
(Donzelli, 2005)

Sustainability: land use in Brazil

*Milhões de hectares**

Área Total	Florestas e Vegetação Nativa	Solo Arável	Outros
851	498	338	15
100%	58%	40%	2%



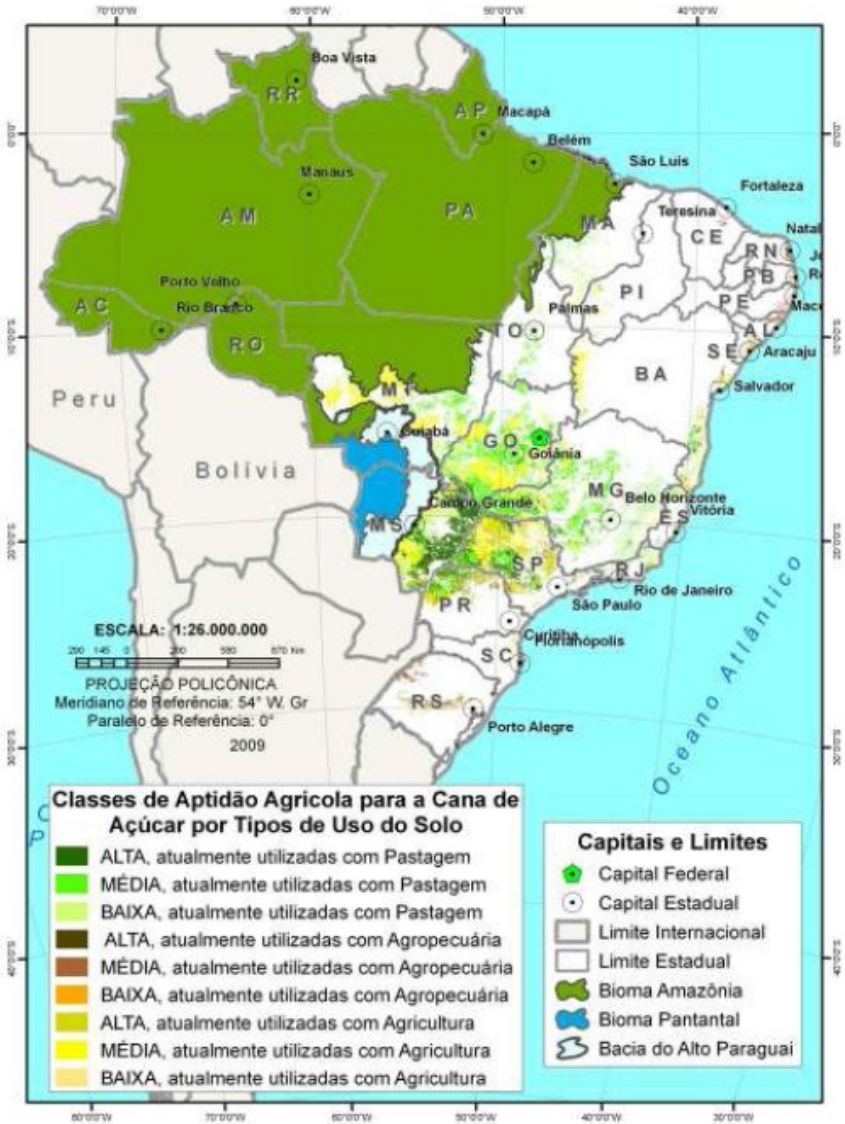


Fontes: Icone, Esalq e IBGE. Elaboração: Cosan eUNICA.

Sustainability: biodiversity and land use

The sugarcane agro-ecological zoning has defined that 65 Mha is available for sugarcane production (new and traditional) respecting environmental constraints and minimum productivity conditions, thus reducing potential conflicts of land use.

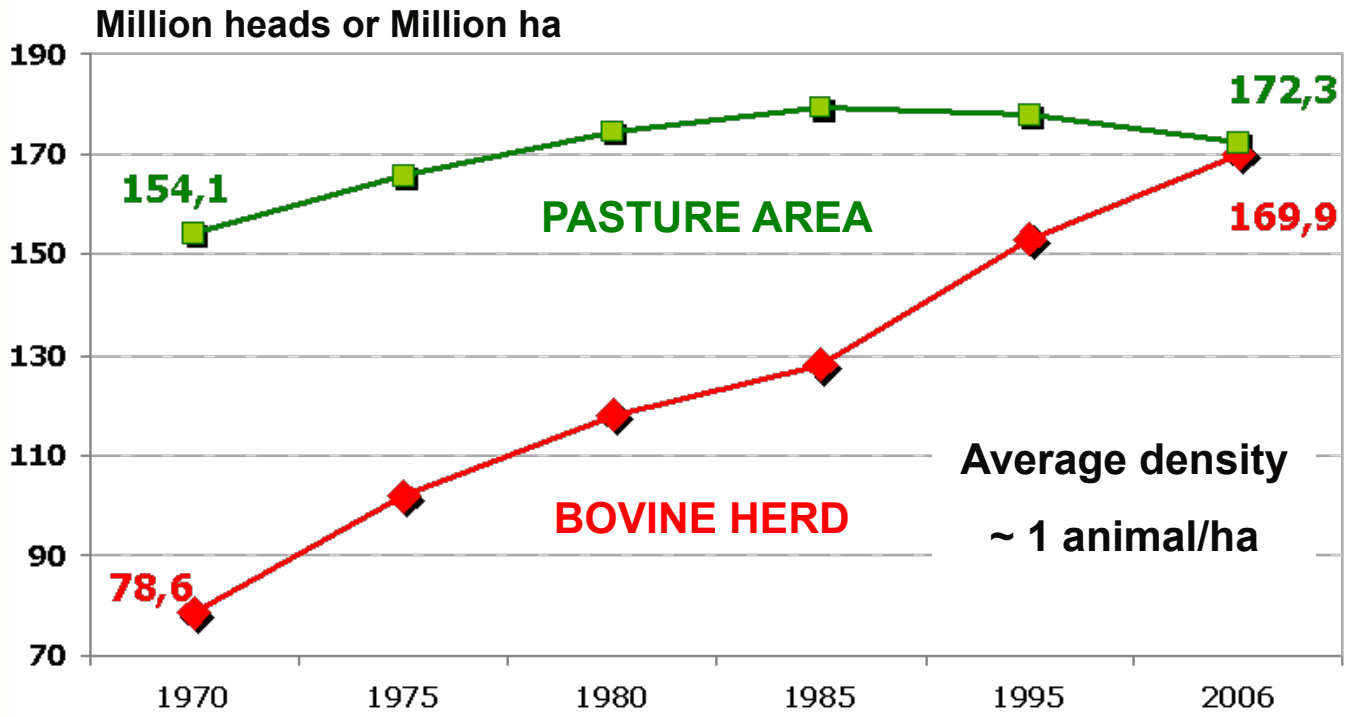
Areas outside these allowed zones do not receive any official support or financing for sugarcane production.



Sugarcane agro-ecological zoning
(MAPA, 2010)

Sustainability: large pasture area available

To reduce the competition for natural resources, efficiency is crucial at any level. For animal protein this aspect is more relevant yet.

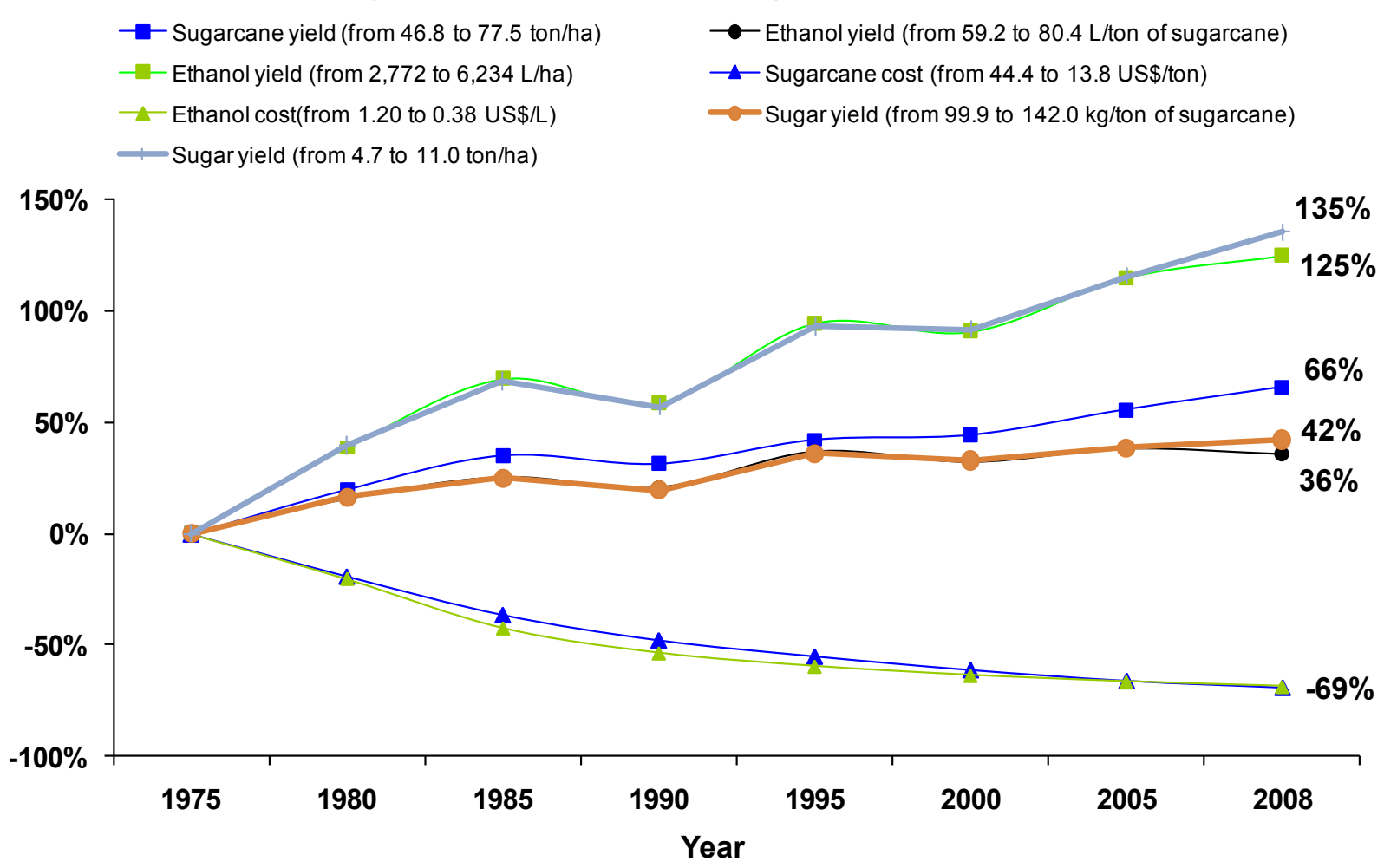


In Brazil, better practices in calf breeding can liberated about 75 M ha.

(FGV, IBGE, 2008)

Sustainability: the economic perspective

Considering the last three decades, the evolution of indicators are positive.



(Lago, 2010)

Sustainability: the social perspective

Besides the positive effects on jobs and income generation, ethanol production has promoted relevant changes in overall social conditions in the regions where sugarcane mills have been installed.

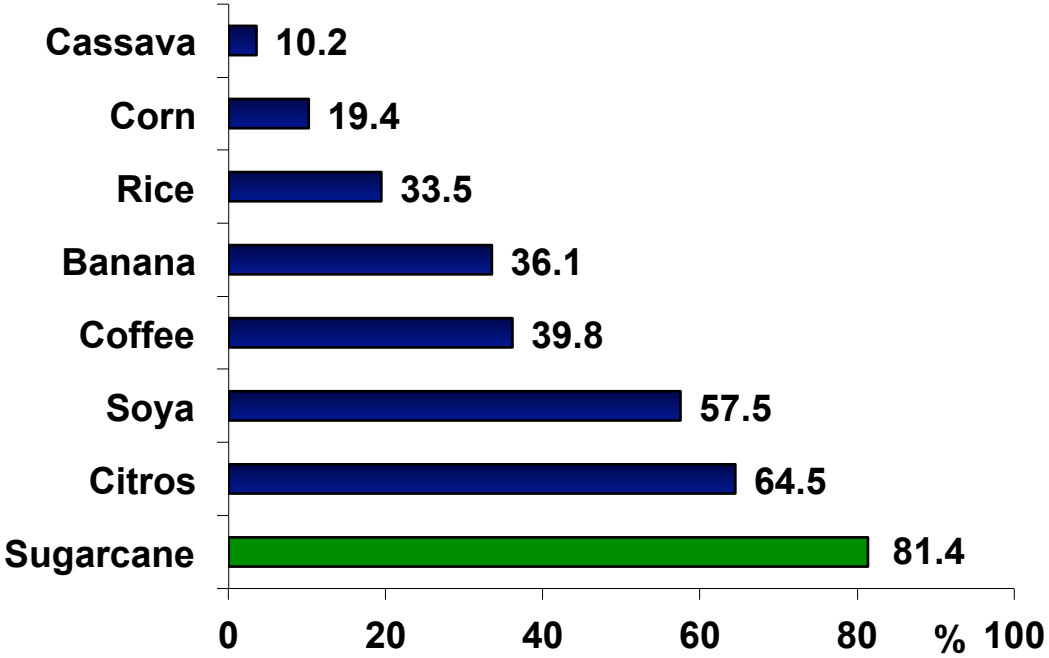
Two aspects has been essential in this process: 1) State public policies, with agencies monitoring and enforcing, and 2) co-operative relation with workers unions, allowing, among other benefits:

- ***Reduction of illiteracy and increase of schooling years (4.3 years for sugarcane workers, 4,0 years for agricultural sector as a whole)***
- ***Increased of formal work relations, assuring rights established in the legislation: retirement and annual vacations remunerated, unemployment insurance, extra monthly wage per year, health programs and improved labor conditions).***
- ***Important reduction of underage workers (from 15.3% in 1981 to less than 0.1% in 2008).***

Sustainability: formal jobs generation

Less than 40% of workers in the Brazilian agriculture is formally employed. With this regard, sugarcane shows the best indicator: about 81.4% of the employees are formally hired, meaning that they had been hired under a formal labor contract.

Fraction of Formal Employment in the Brazilian Agriculture, 2007

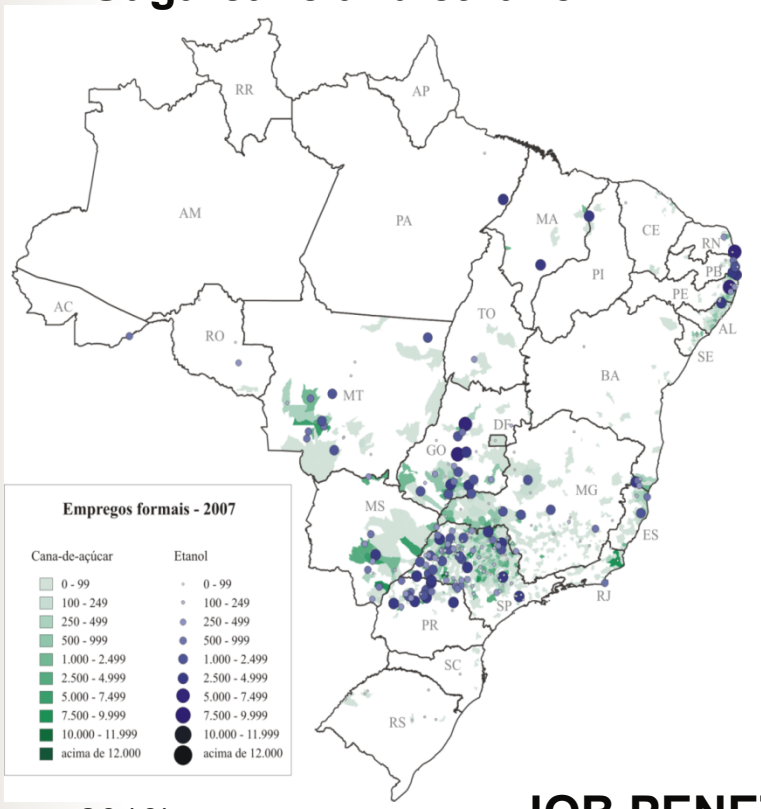


(Moraes, 2010, based on IBGE data)

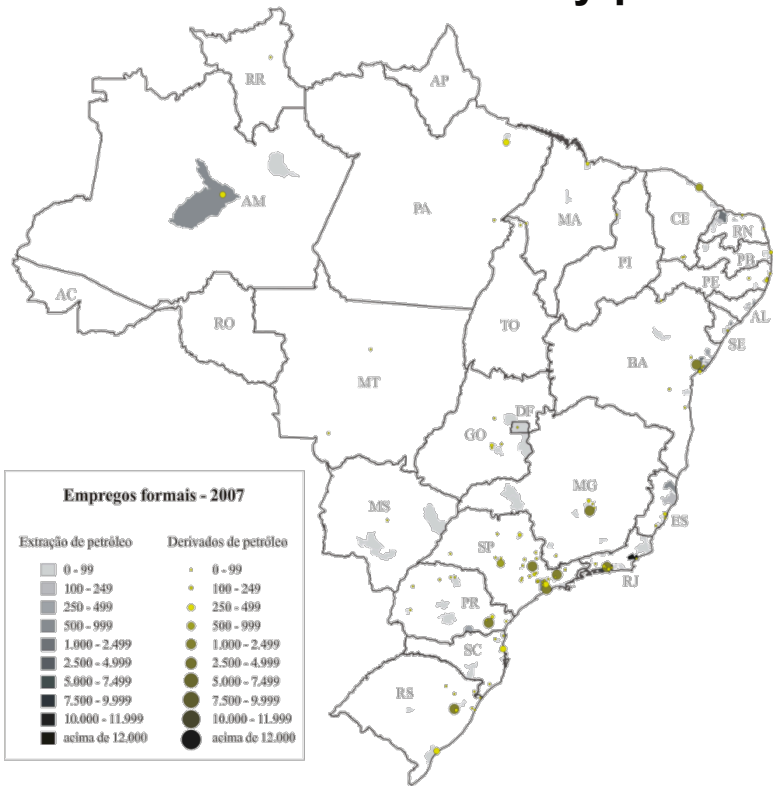
Sustainability: spatial distribution of jobs

The Brazilian ethanol agro-industry employs more than 6 times the number of workers employed in petroleum production, with high penetration and interiorization of generated jobs.

Sugarcane and ethanol



Petroleum extraction and oil by-products

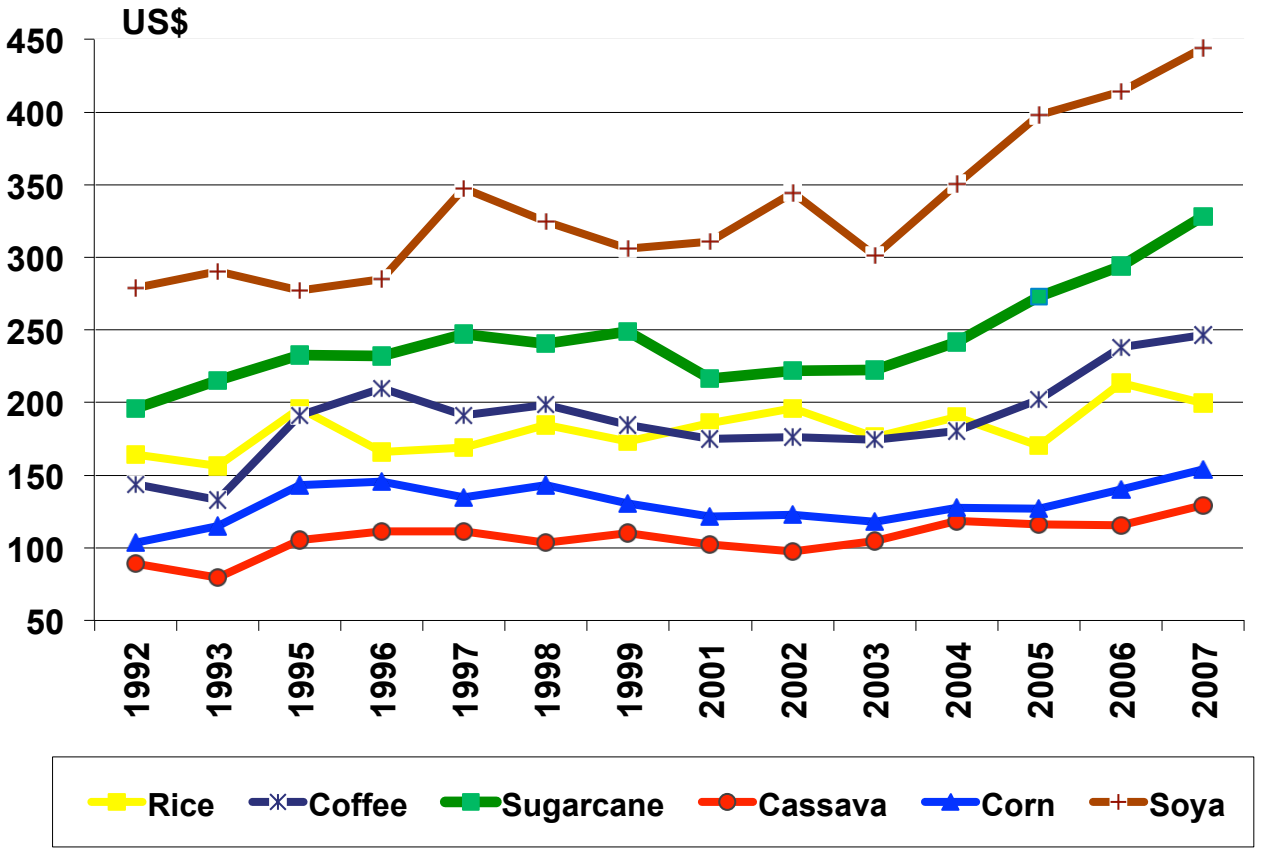


(Moraes, 2010)

JOB PENETRATION - 2007

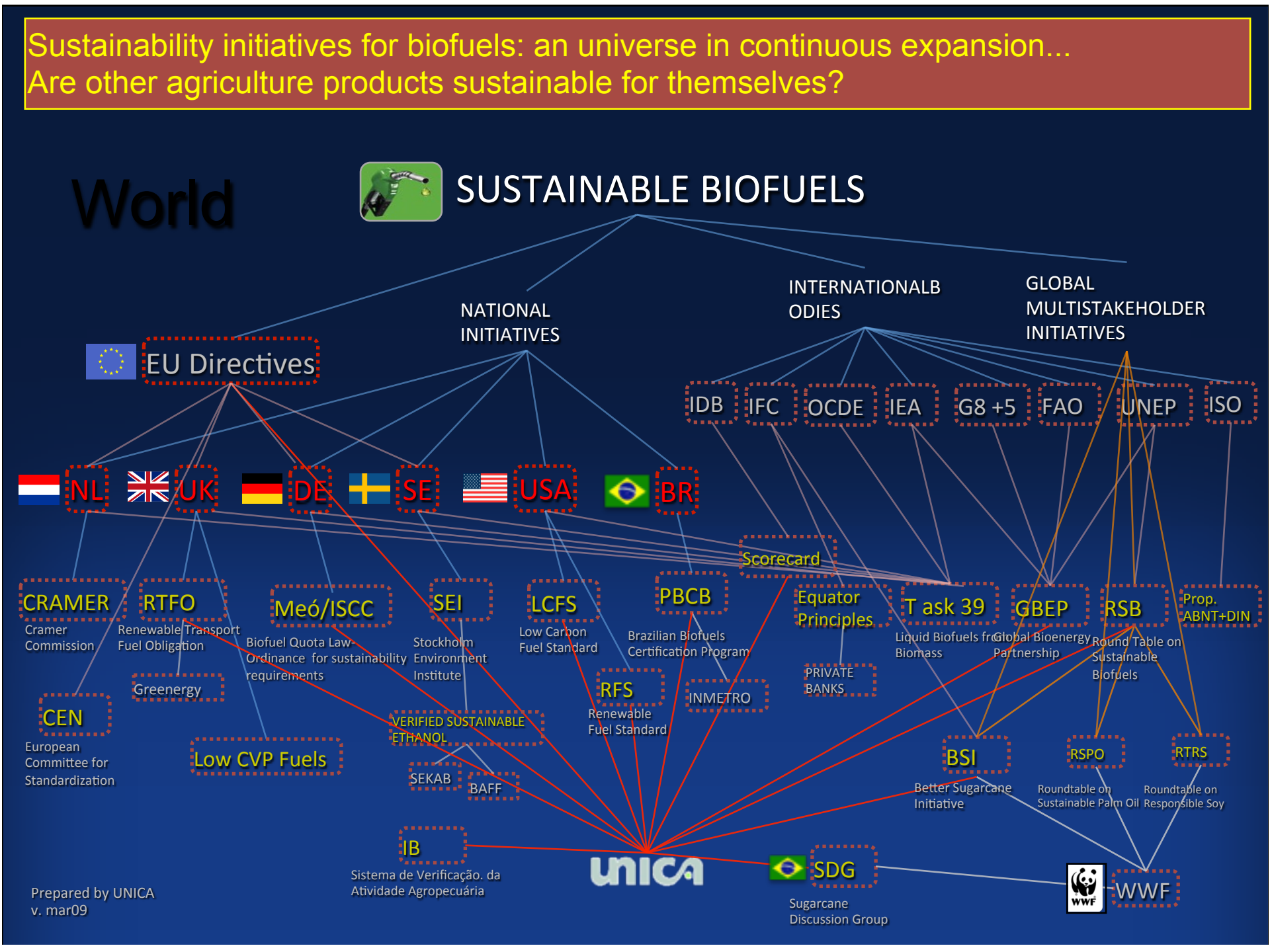
Sustainability: better wages

The average monthly wage of sugarcane workers in comparison with sugarcane wages are better than the agriculture national average.



(Moraes, 2010 based on IBGE data)

Sustainability initiatives for biofuels: an universe in continuous expansion...
Are other agriculture products sustainable for themselves?



Sustainability: new frontiers

1. Biofuels utilization in cane agriculture and transport

Fuel corresponds to approx. 40% of energy consumed in sugarcane production. During the 80's, alternatives for replacing the conventional diesel oil used in sugarcane agriculture were evaluated.

Basically two routes were assessed, with a limited outcome:

- ✓ ***Ethanol additivation (lubricity and cetane improvers) to allow its use in conventional Diesel motors.***
- ✓ ***Diesel engine conversion ("Ottolization"), reducing compression rate and adding ignition systems in order to make possible hydrous ethanol use.***

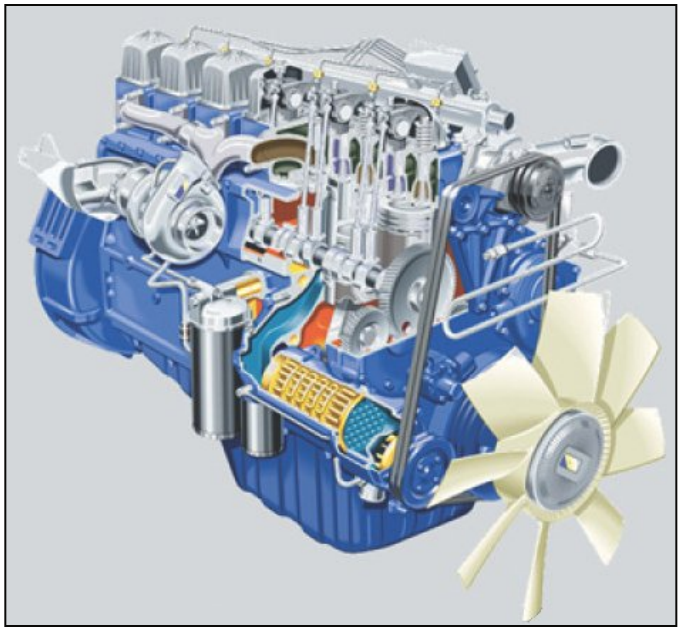
Tractor for ethanol use
(66 CV, carbureted electronic ignition)
(Ford, 1985)

Sustainability: new frontiers

1. Biofuels utilization in cane agriculture and transport

More recently:

- ***High performance Diesel engines using low additivation (5%) hydrous ethanol have been launched (Scania, 2008).***
- ***Biodiesel has been regularly used. Since January 2010 all diesel used in Brazilian trucks has 5% biodiesel (B5).***



Electronic injection Diesel engine for hydrous ethanol (270 CV) (Scania, 2008)

Sustainability: new frontiers

1. Biofuels utilization in cane agriculture and transport

Considering biofuels utilization in agriculture operations and sugarcane transportation, five scenarios were evaluated, taking into account current and prospective conditions of composition and feedstock used in biofuels.

Reference scenario: conventional diesel oil

Scenario 1: current B5 (methyl biodiesel, 85% soybean oil, 15% tallow)

Scenario 2: improved B5 (methyl biodiesel, 85% palm oil, 15% tallow)

Scenario 3: optimized B100 (ethyl biodiesel, 85% palm oil, 15% tallow)

Scenario 4: E100 (hydrous ethanol, 5% cetane improver additive)

Sustainability: new frontiers

1. Biofuels utilization in cane agriculture and transport

To estimate the impact of different fuels on energy consumption and GHG emissions associated to ethanol production and use, a set of data was prepared, considering the current and prospective Brazilian conditions.

Diesel and Biofuels basic data (Horta Nogueira, 2010)

Biofuel	Fossil energy consumption in production (MJ/L)	GHG emission factor (kg CO_2/L)
Convencional diesel oil	41,22	2,489
Methyl soybean oil biodiesel	11,16	1,019
Methyl tallow biodiesel	5,50	0,469
Methyl palm oil biodiesel	10,53	0,796
Ethyl palm oil biodiesel	7,40	0,250
Ethyl tallow biodiesel	2,25	0,135
Hydrous ethanol, additived	2,71	0,257

Sustainability: new frontiers

1. Biofuels utilization in cane agriculture and transport

For more details on the energy balance and emissions for biodiesel production in Brazil:

Energy xxx (2010) 1–8

Contents lists available at ScienceDirect

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Does biodiesel make sense?

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ABSTRACT

In several countries biodiesel blending programs have been implemented looking for reduction in fossil fuel dependence and environmental benefits, including climate change mitigation. The current global biodiesel production, from different fatty raw materials, reaches about 6 billion liters per year and represents 10% of whole biofuel production. Nevertheless, in many cases the actual advantages of biodiesel production and usage are not clearly evaluated. Essentially, the feasibility of biodiesel production can be determined by its efficiency in solar energy conversion, as indicated by agro-industrial productivity and energy balance parameters, which expresses a relative demand of natural resources (land and energy) to produce biofuel. Taking into account the Brazilian conditions, in this paper an assessment of biodiesel production is presented, comparing four different productive systems. According to this evaluation, soybean and castor are limitedly feasible, whereas tallow and palm oil represent more suitable alternatives. The selection of an efficient productive system is crucial for the rationality of biodiesel production.

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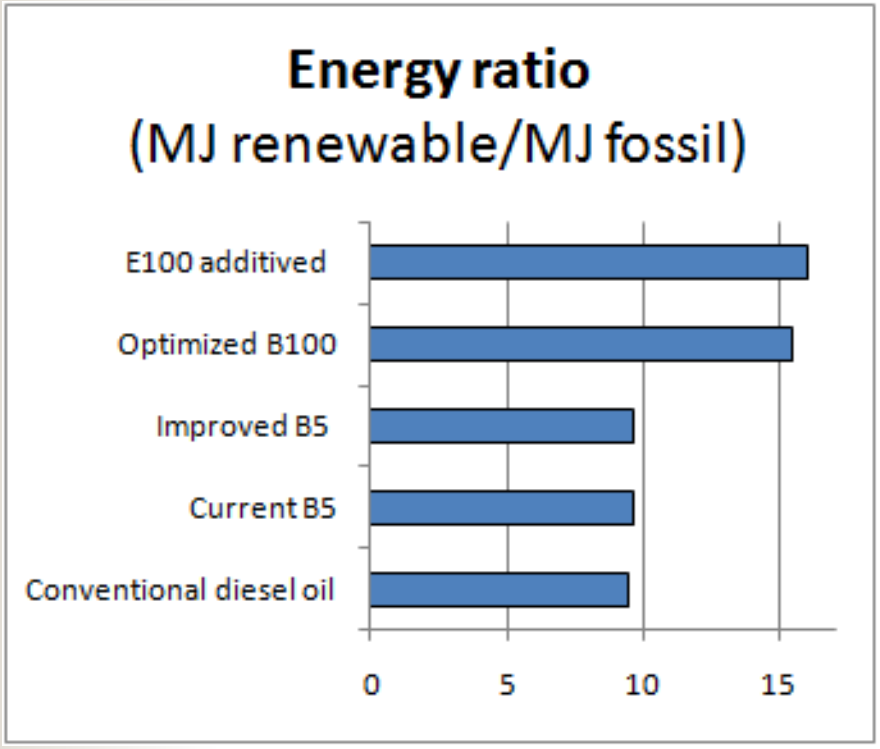
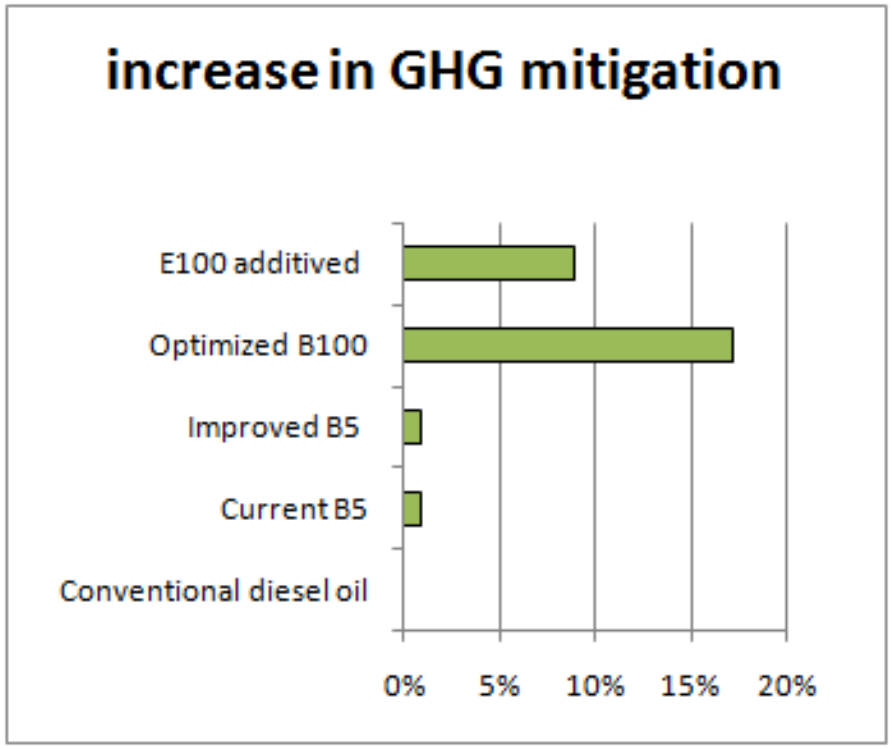
Sustainability: new frontiers

1. Biofuels utilization in agriculture and transport

Assuming a typical South-Center mill operation, the impact on renewable energy yield and GHG mitigation were assessed.





Sustainability: new frontiers

2. Increase of sugarcane mill capacity

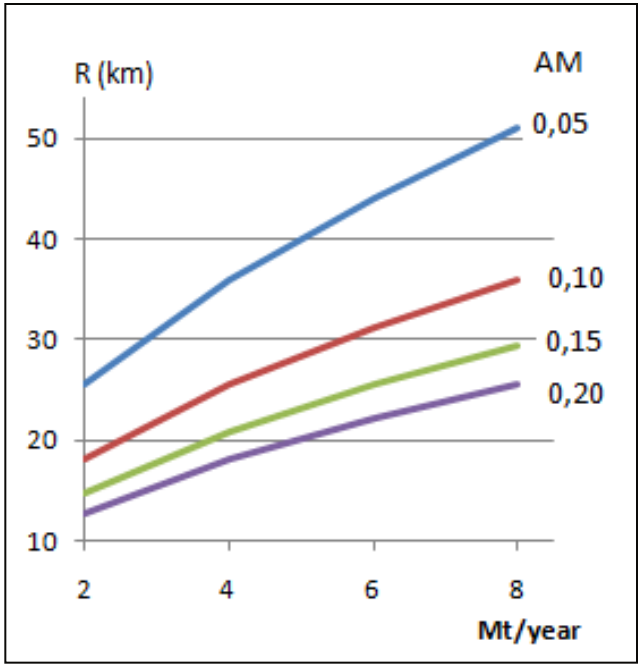
Induced by the scale factor in the cost of industrial equipment, the expansion of ethanol production in new areas has been associated with the increase of processing capacity. In the last two years the average capacity rose 9.5%.

In this context, is important to assess the impact of increase in sugarcane transportation energy cost, which can be reduced by the intensification of cultivated areas in the mills vicinity.

Sustainability: new frontiers

2. Increase of sugarcane mill capacity

To evaluate the effect of mill capacity on energy demand and thus on GHG emission, it was adopted as parameter the average densification of sugarcane fields, which is the ratio of the sugarcane cultivated area (determined by the capacity) and the area determined by the average distance of transport.

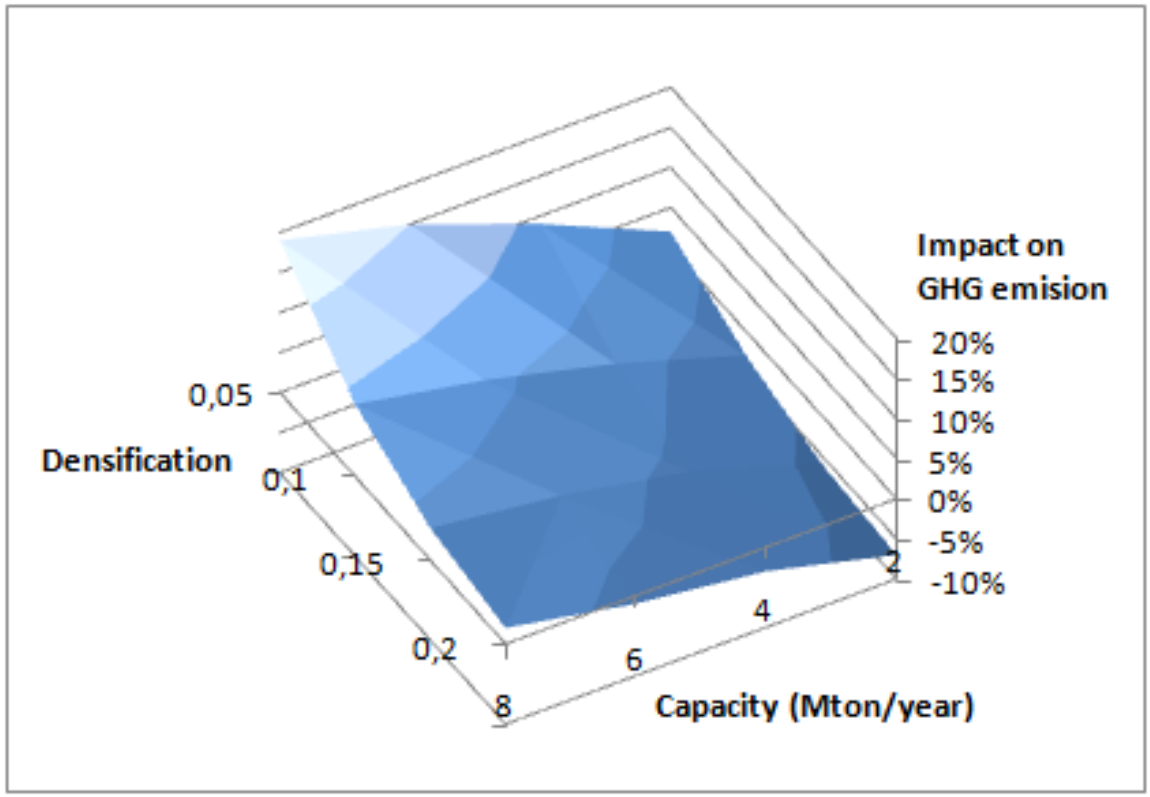


$$AM = \frac{\text{Sugarcane cultivated area}}{\text{Total area as defined by the average radius of transport}} = \frac{0{,}01.\,AC_{ref}}{\pi.\left(\frac{3.\overline{R}_{transp}}{2}\right)^2}$$

Sustainability: new frontiers

2. Increase of sugarcane mill capacity

Considering as baseline a typical ethanol mill (2,27 Mtc/ano, R=23 km, AM=7%, 36,8 MJ/tc), it was possible to evaluate the effect of increasing capacity on sugarcane transport energy and GHG emission.



GHG emission as function of mill capacity and sugarcane field concentration

Sustainability: new frontiers

3. Adoption of efficient modals in ethanol logistic

The recent expansion of ethanol production in Brazil has fostered investment in logistics, particularly in more efficient transportation modals, such as pipelines and barges, considering also ethanol trade.

In the next years new systems of ethanol transport will be in place, reducing costs and improving efficiency in the whole production-use chain.

Sugarcane barges in Tiete-Paraná waterway (Globo Rural, 2009)

Sustainability: new frontiers

3. Adoption of efficient modals in ethanol logistic

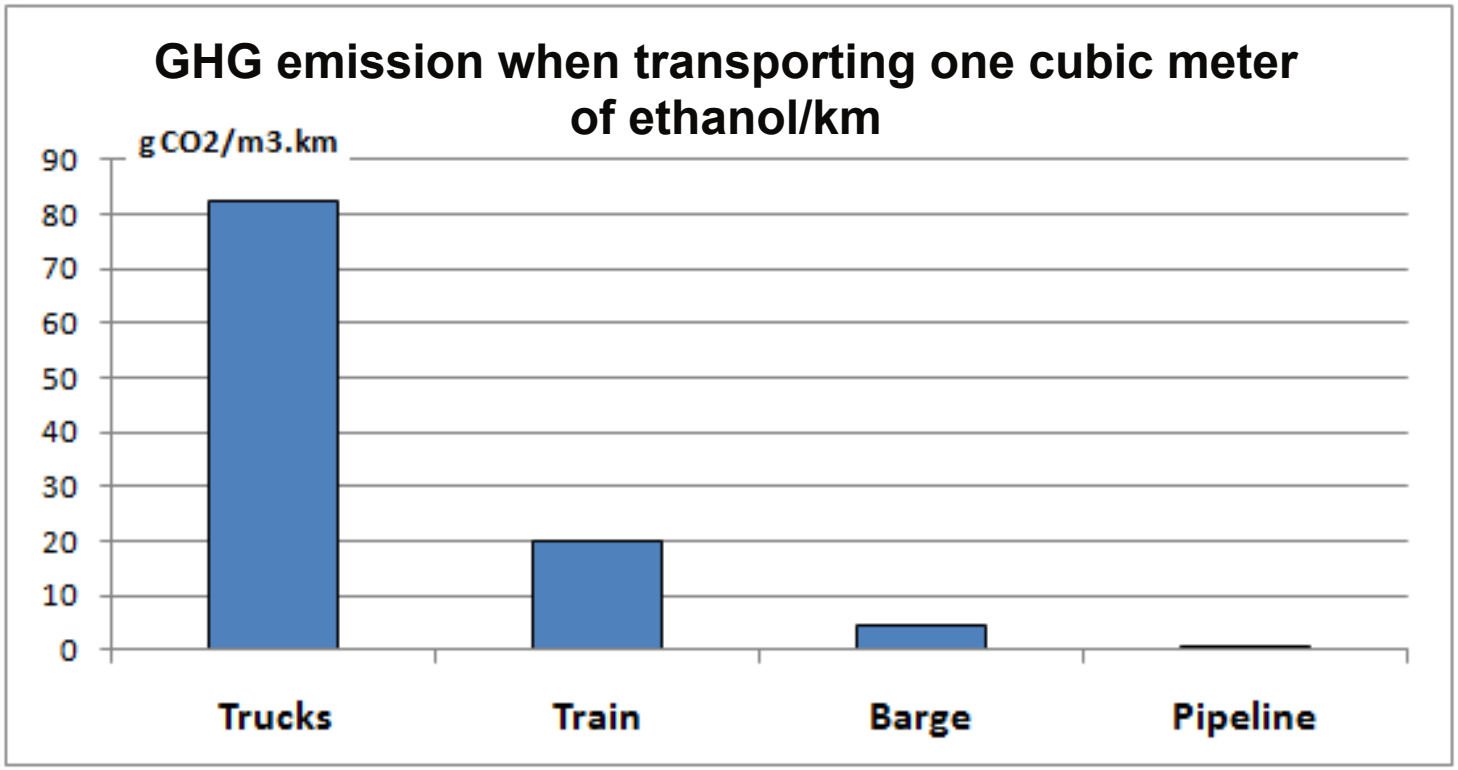
A relevant initiative put forward to reduce logistic cost is Logum venture, joining six big Brazilian companies (*Copersucar, Cosan, Odebrecht , Petrobras, Camargo Corrêa e Uniduto*) in a R$ 7,0 billion deal to establish a 1,300 km pipeline for ethanol connecting new production areas to exporting harbors, able to move annually about 20 million cubic meters of ethanol.

Logum multimodal main routes (Logum, 2011)

Sustainability: new frontiers

3. Adoption of efficient modals in ethanol logistic

Modeling the energy performance of different modals is possible to assess the GHG emission for ethanol transportation in each alternative.

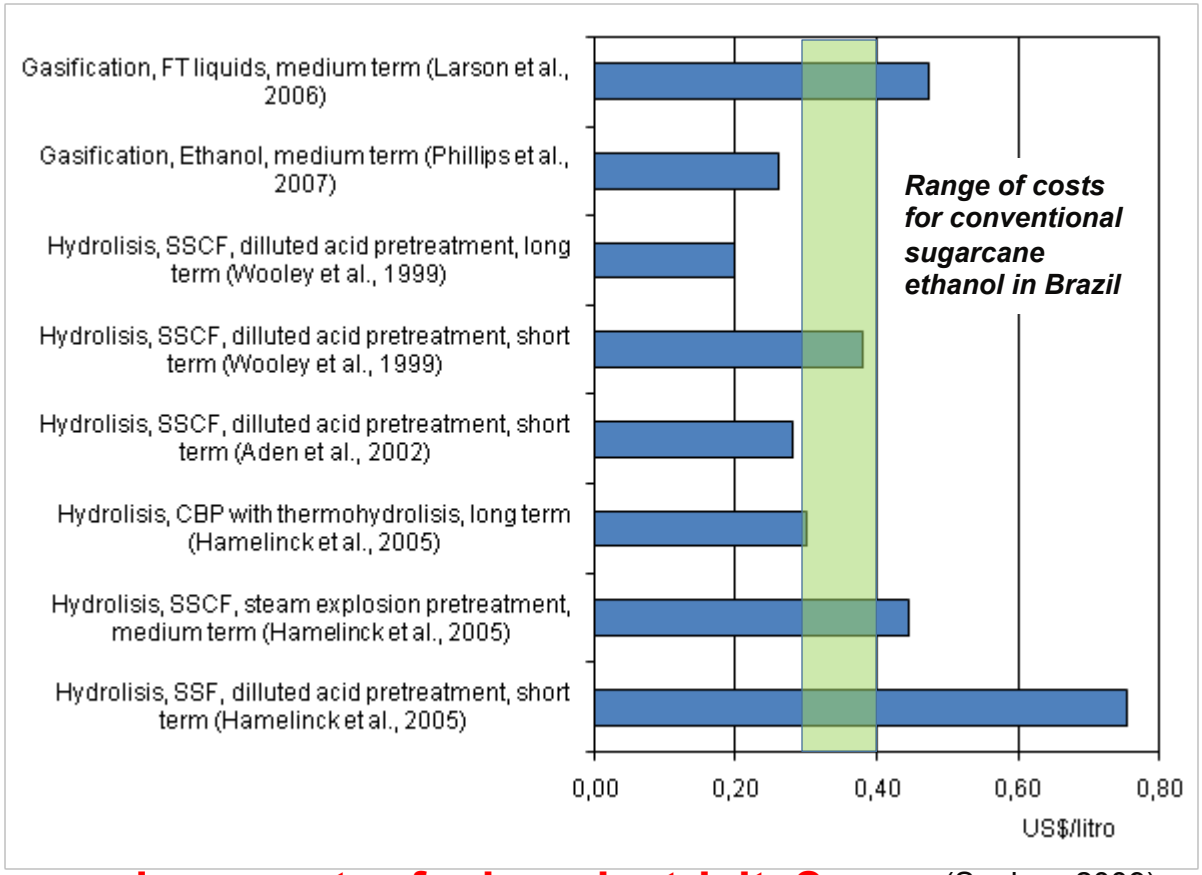


Sustainability: new frontiers

4. New processes for bagasse valorization

Introduction of new processes can improve its performance and increase the amount of ethanol produced per hectare.

Ethanol from bagasse demonstration plant, DEDINI (5,000 liters/day)

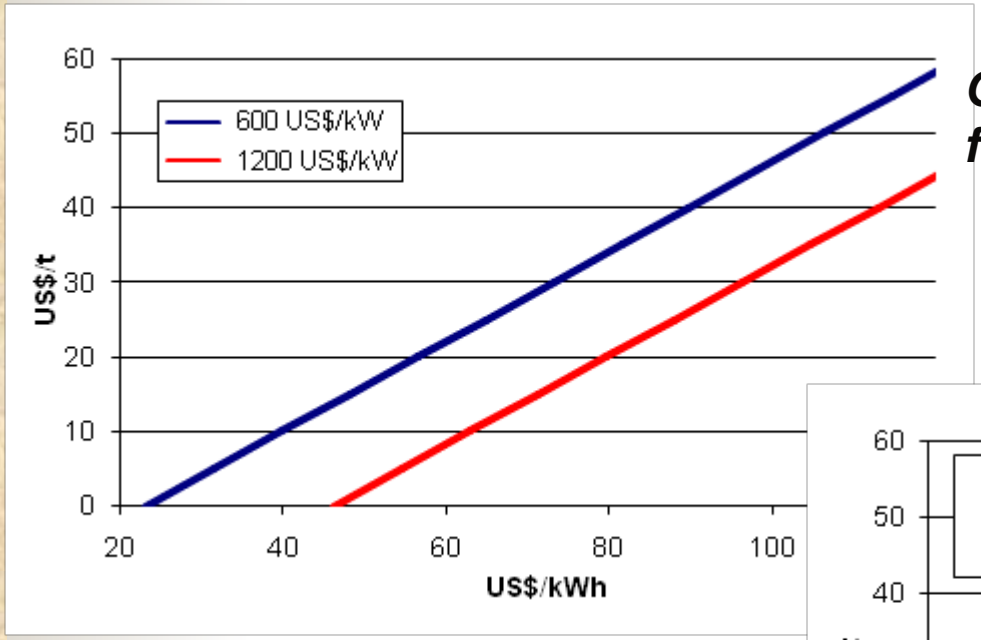


What is more attractive to produce: motor fuel or electricity?

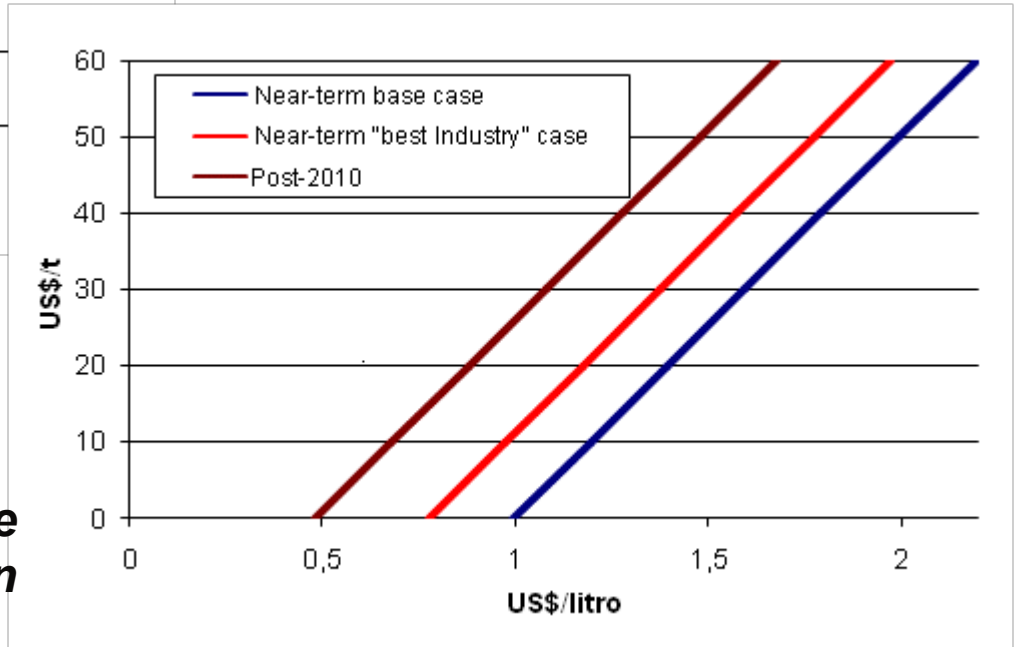
(Seabra, 2009)

Bioethanol or bioeletricity?

From a Brazilian point of view and considering current costs and prices scenarios, sugarcane bagasse is more valuable for power.



Opportunity value of bagasse for power production.



Opportunity value of bagasse for ethanol production

Final comments

Bioethanol from sugarcane offer an effective approach to face the new challenges posed by climate change, energy and food security and socio-economic activation.

The current performance of this route is the highest among all other biofuel productive systems (feedstock + processing). Besides, there are relevant opportunities for additional improvements.

In this direction, efficiency is name of the game.

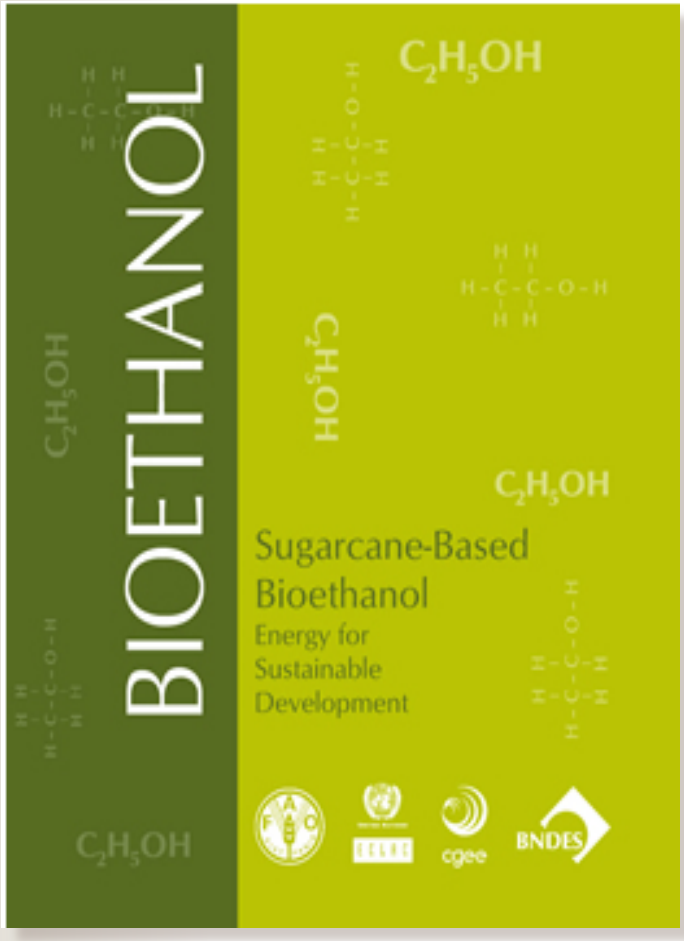
Sugarcane Ethanol: Energy for Sustainable Development

Horta Nogueira, editor

FAO CEPAL CGEE BNDES co-edition, 300 pg, 2008

Available in English, Spanish, French and Portuguese

Download free at: http://www.sugarcanebioethanol.org



Contents

1. ***Bioenergy and biofuels***
2. ***Ethanol as a vehicle fuel***
3. ***Bioethanol production***
4. ***Co-products of sugarcane bioethanol***
5. ***Advanced technologies in the sugarcane agro-industry***
6. ***Sugarcane bioethanol in Brazil***
7. ***Sustainability of sugarcane bioethanol: the Brazilian experience***
8. ***Perspectives for a global biofuel market***
9. ***An outlook for bioethanol fuel***

Routes to Cellulosic Ethanol

Buckeridge and Godman, editors

Springer, 2011

Part 1, 27-41 DOI: 10.1007/978-0-387-92740-4_3

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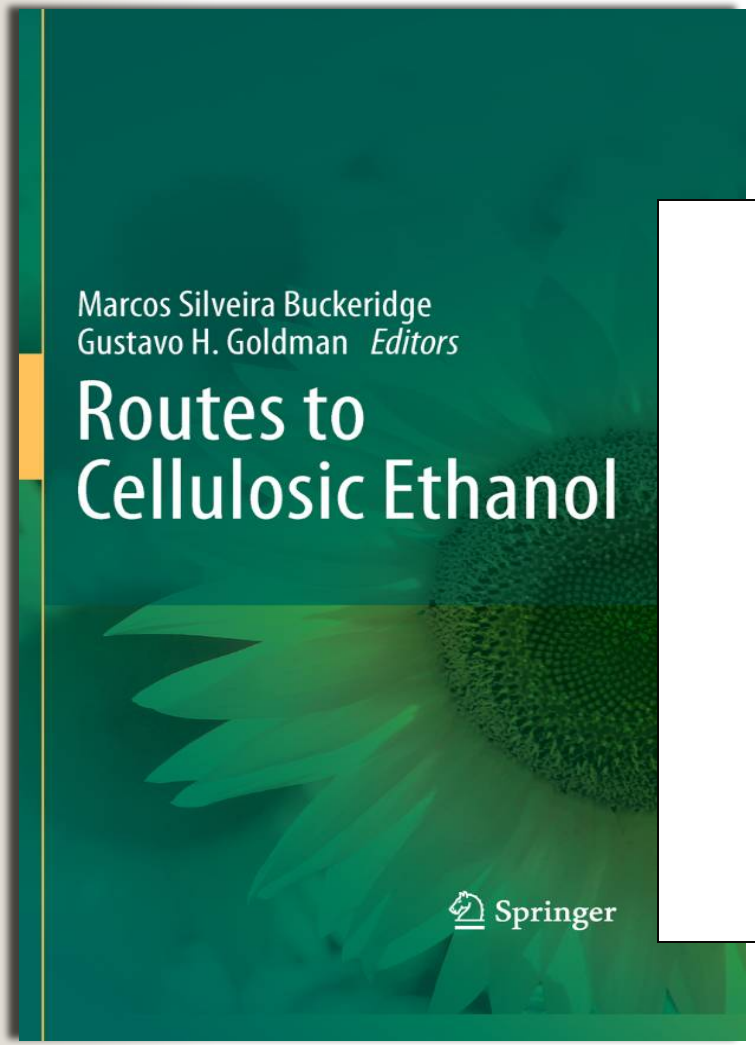


Chapter 3
Biomass Gasification for Ethanol Production

Luiz A.H. Nogueira, Joaquim E.A. Seabra, and Isaías C. Macedo

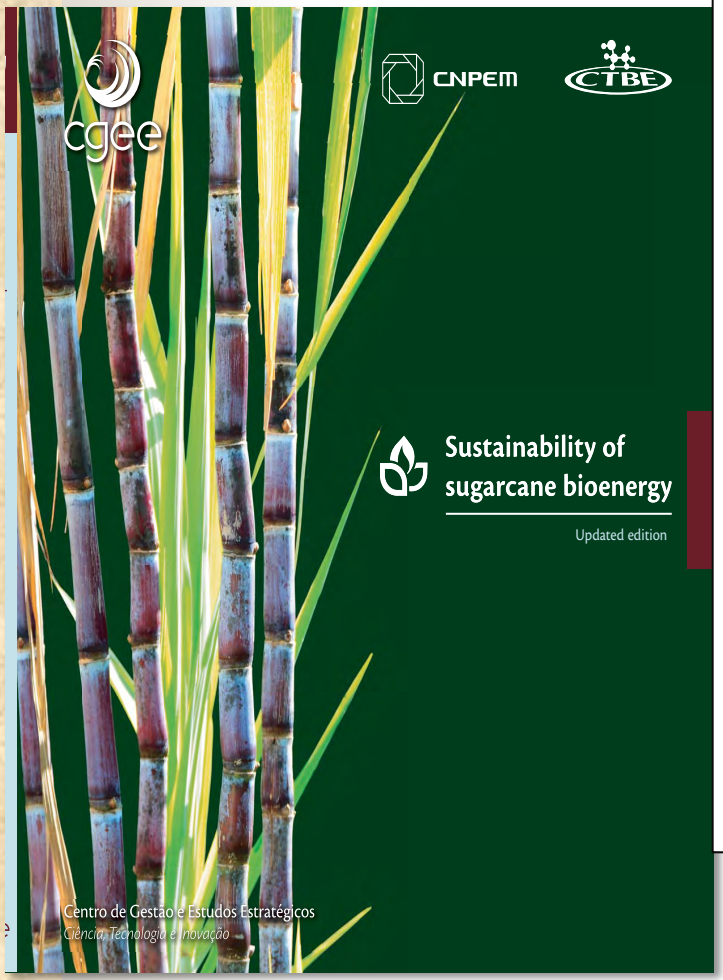
1 Introduction

For a sustainable future, it is essential for mankind to access the largely untapped solar resource by innovative bioenergy routes, an important way to overcome fossil fuel dependence and mitigate related environmental impacts. In this framework, as a good example of the potential to be exploited, among the several biomasses under scrutiny to be used for energy supply, sugarcane appears as one with the most

Sustainability of Sugarcane Bioenergy

Poppe and Cortez, editors
CGEE/CTBE/NIPE, 360 pg. ISBN 978-85-60755-47-9, 2012
Launched during the Rio+20 Conference

Download free at: http://www.cgee.org.br/publicacoes/sustainability.php



PART I
Introduction

Chapter 1
International negotiations on bioenergy sustainability

Chapter 2
Main trends on sustainability of sugarcane production systems

PART II
Sugarcane bioenergy chain

Chapter 3
Agro-industrial technological paths

Chapter 3A
Fertilizer concerns

Chapter 4
Water usage in bioethanol production in the State of São Paulo

Chapter 5
Sugarcane bioethanol and bioelectricity

Chapter 6
Bioethanol use in light vehicles

PART III
Integrated production systems and land use

Chapter 7
Sugarcane cropping and cattle husbandry integration

Chapter 8
Sugarcane agro-industrial facilities and greenhouses integration

Chapter 9
Direct and indirect land use change assessment

PART IV
Indicators and certification issues

Chapter 10
Evolution of environmental, social and economic indicators

Chapter 11
Certification for sugarcane production processes

PART V
Life cycle analysis, energy and greenhouse gases balance

Chapter 12
Energy and GHG emissions in Brazil and worldwide

Chapter 13
Life cycle GHG emissions of sugarcane bioenergy

Chapter 14
Fossil energy use and greenhouse gases emission in the integrated production of bioethanol and biodiesel

Chapter 15
Contribution of sugarcane bioenergy to the Brazilian energy matrix

Chapter 16
Contribution of sugarcane bioenergy to the Country's greenhouse gas emission reduction

PART VI
Post-scriptum

Chapter 17
From the sugarcane ethanol sustainability that we have to the sugarcane ethanol sustainability that we should have

Obrigado por sua atenção.

L. A. Horta Nogueira

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EXCEN, Universidade Federal de Itajubá

Minas Gerais, Brazil

VIII CBPE

Mesa Redonda: Fronteiras agro-energéticas

Desafios para o planejamento e a regulação do mercado de biocombustíveis

Tópicos:

1. *Esperanças globais, contradições locais*
2. *Causas e consequências*
3. *Condições de contorno*
4. *Políticas públicas em bioenergia*
5. *Conclusões*

1. Esperanças globais, contradições locais

Apesar das perspectivas positivas e suas vantagens comparativas, o setor sucroenergético atravessa uma crise difícil no Brasil.

Praticamente não existem projetos de novas usinas, dezenas de unidades não estão operando nessa safra e tem sido limitada a renovação dos canaviais, com redução da oferta de matéria-prima.

Diversos fatores, internos e externos à indústria, estão associados à essa crise, como problemas climáticos, efeitos da adoção de novas tecnologias, elevação de custos.

As questões financeiras, que colhem o setor em meio a um processo expansivo, são mais graves e foram detectadas pelo CONAB ainda em 2008.

1. Esperanças globais, contradições locais

Em poucos anos, de 2008 até hoje;

- ✓ ***A produção de etanol recuou 5 anos, caindo em cerca de 30%. Existem 41 usinas paradas nessa safra.***
- ✓ ***O teor de etanol na gasolina foi reduzido (de 25% para 20%) e uma MP (abril/2011) baixou o limite inferior de mistura para 18%.***
- ✓ ***Brasil se converteu de exportador em importador de etanol.***
- ✓ ***A Petrobras passou a importar volumes crescentes de gasolina, em condições gravosas, e reconfigurou o projeto das novas refinarias, priorizando a produção de gasolina.***

Por que estamos assim?

2. Causas e consequências

A perda de competitividade do etanol de cana de açúcar foi determinada essencialmente devido à intervenção governamental na formação de preços da gasolina, mantida em níveis artificialmente baixos.

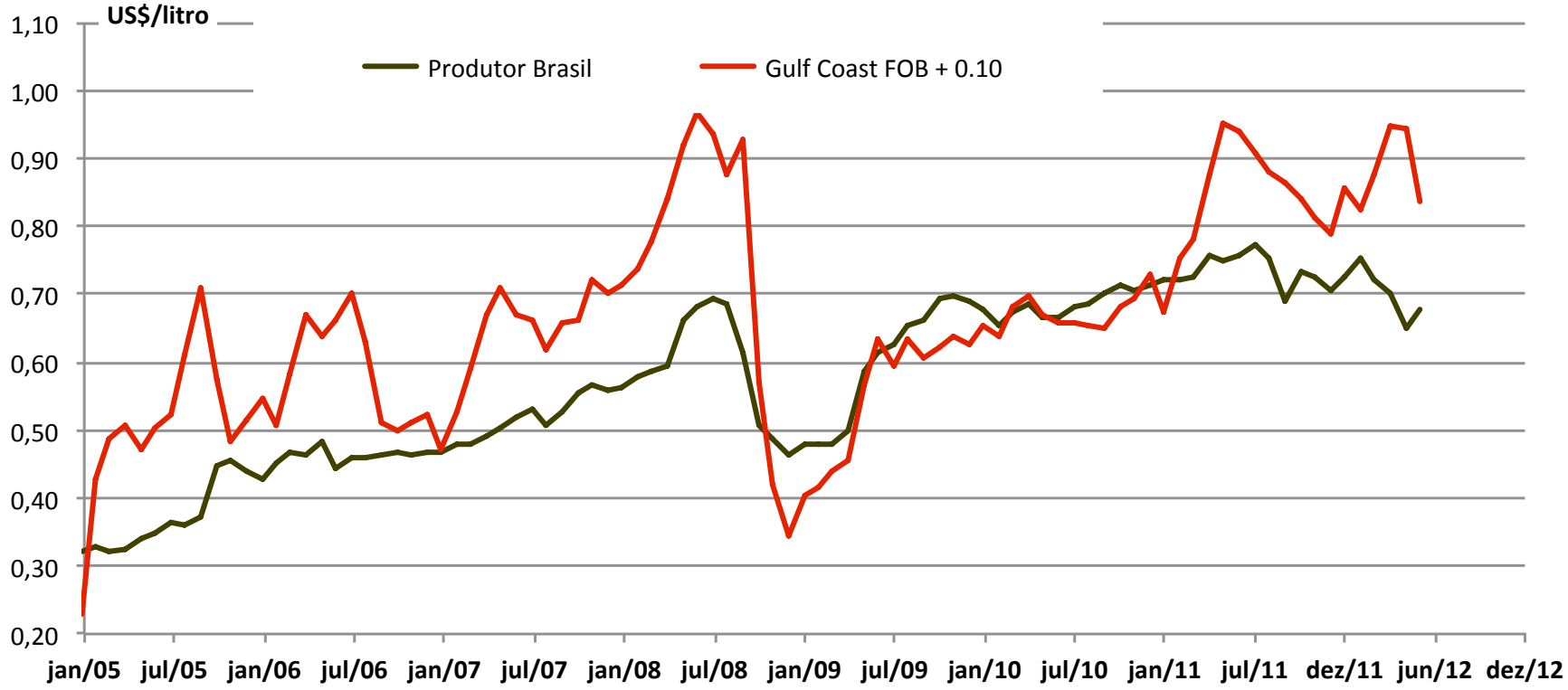
Em um mercado consumidor com predomínio de veículos flex, o consumo de etanol foi diretamente afetado.

As medidas governamentais ocorrem em duas vertentes:

1. ***Intervenção no preço de realização da Petrobras, que se desconectou do preço de paridade internacional desde 2004.***
2. ***Redução progressiva (até a eliminação) dos tributos federais sobre os derivados de petróleo.***

2. Causas e consequências

Preços ao Produtor da Gasolina regular, sem tributos



Fontes: ANP, 2012; IPEADATA, 2012 e IEA, 2012

Paridade de preços: conceitos, influência da taxa de cambio, condições FOB/CIF...

2. Causas e consequências

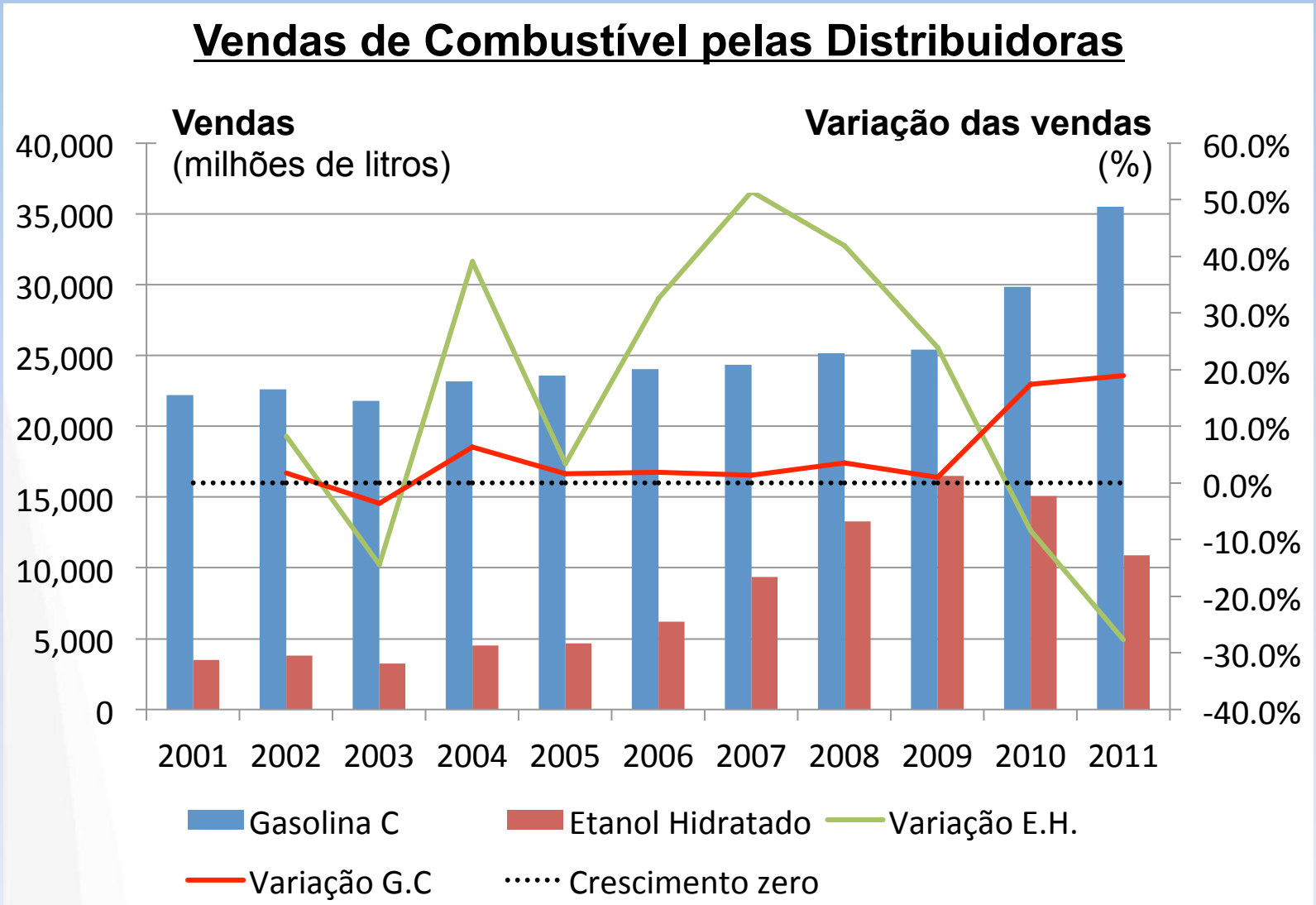
A ausência de paridade de preços no mercado de combustíveis tem provocado pesados prejuízos à Petrobras. Frequentemente dirigentes dessa empresa têm sinalizado a necessidade de ajustes nos preços de seus produtos.

Em seu último balanço (2º trim. de 2012), foram registradas perdas superiores a R$ 7 bilhões, agravando o quadro observado em 2011.

Esse prejuízo foi o principal determinante do resultado negativo da companhia no período. Todas as demais áreas apresentaram lucros.

Paradoxalmente, quanto mais vende gasolina, mais a Petrobras tem perdas. E com os preços artificialmente baixos, a demanda de gasolina cresceu fortemente.

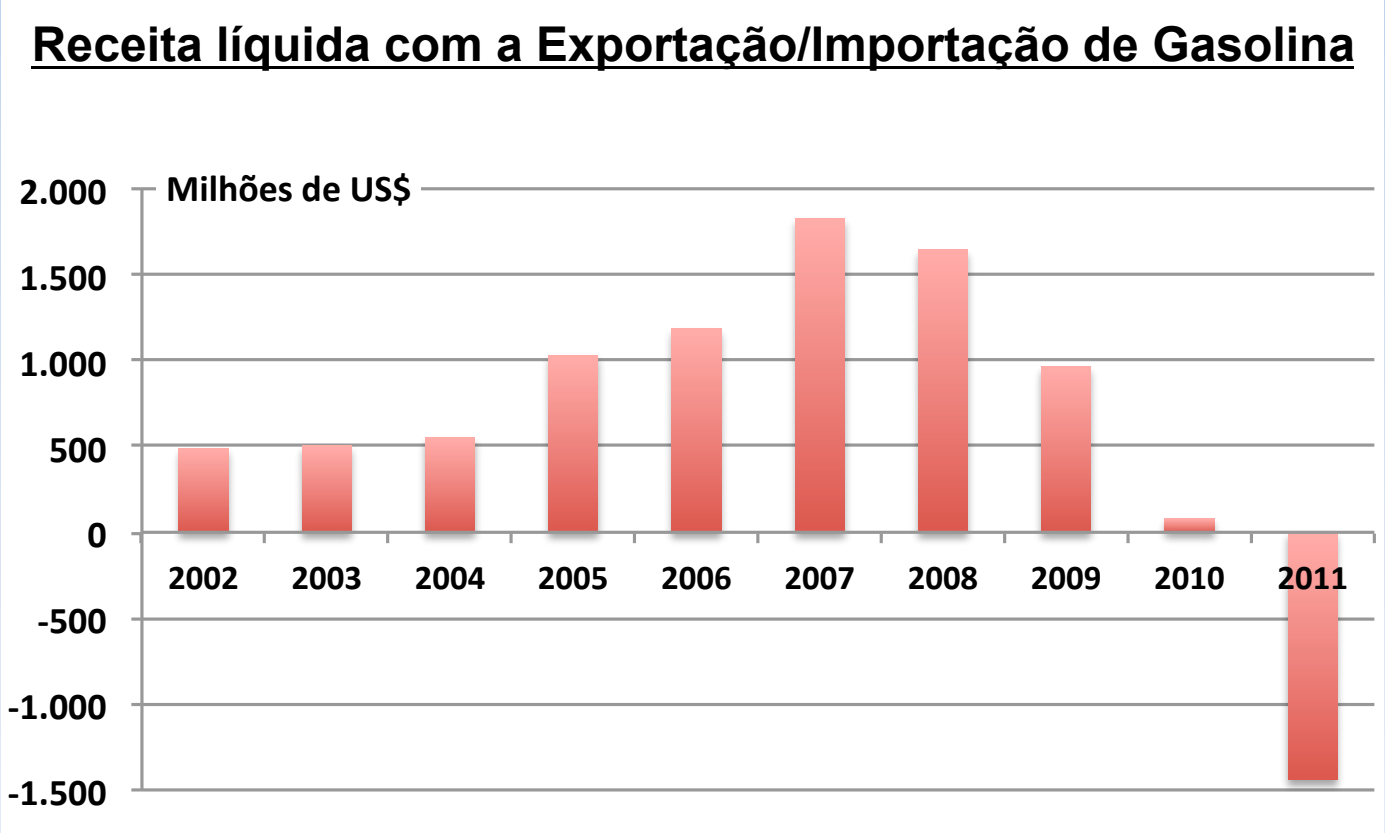
2. Causas e consequências



Fonte: ANP, 2012, Elaboração: Neves, M.F./ Markestrat

2. Causas e consequências

Do ponto de vista das contas nacionais, a política de preços indutora de importações implicou em um dispêndio de US$ 1,4 bilhões com a importação de gasolina em 2011. Essa conta era positiva até 2010.



Fonte: ANP, 2012

2. Causas e consequências

A redução dos tributos federais (CIDE) sobre a gasolina foi promovida de modo combinado com a elevação do preço para a Petrobras, de forma a manter o preço final estável.

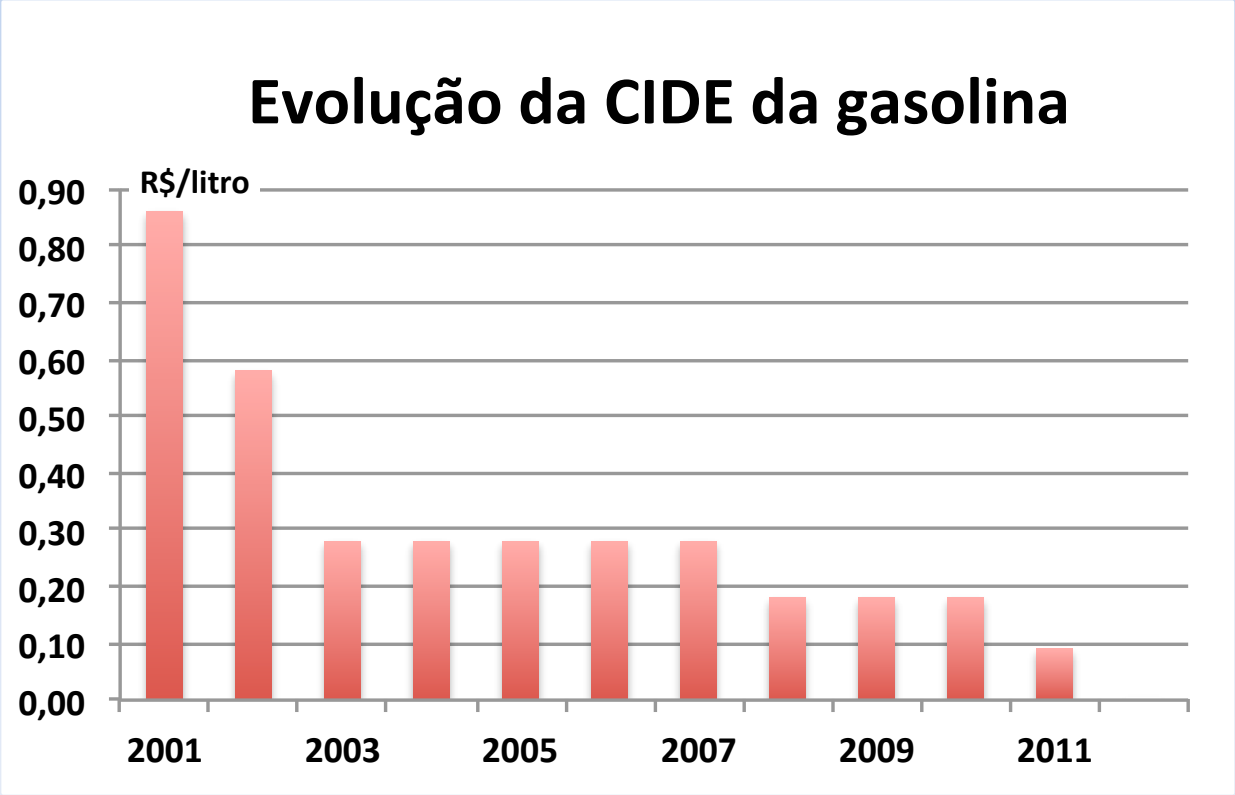
Criada em 2001 por Emenda Constitucional, a CIDE (Contribuição de Intervenção no Domínio Econômico) sobre os combustíveis e seus recursos devem ser aplicados em:

1. ***programas ambientais para reduzir os efeitos da poluição causada pelo uso de combustíveis;***
2. ***subsídios à compra de combustíveis;***
3. ***infra-estrutura de transportes***

Os estados e municípios recebem repasses correspondentes a 29% do valor arrecadado pela CIDE, que somaram mais de R$ 12 bilhões entre 2004 e 2010 (MF, 2012).

2. Causas e consequências

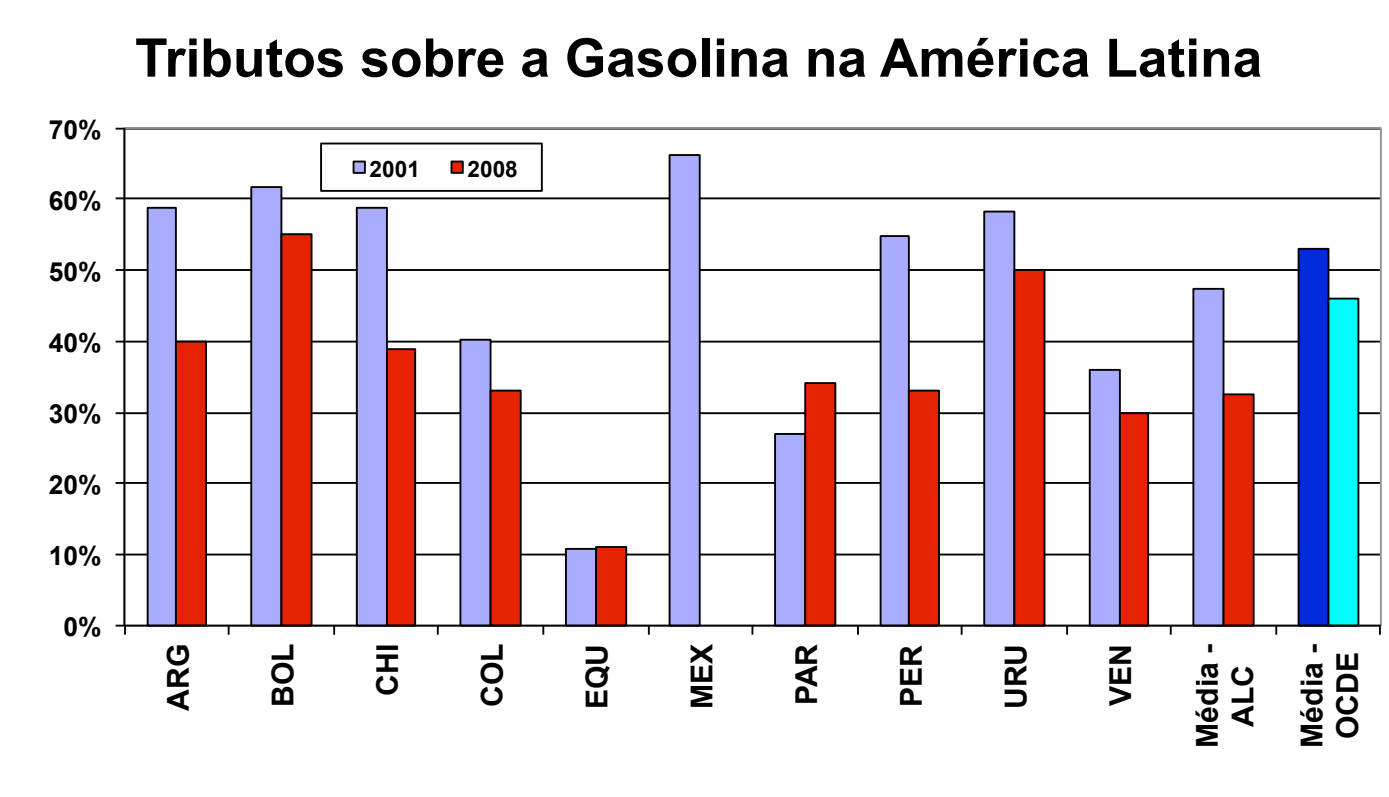
As perdas de arrecadação associadas à redução da alíquota da CIDE de 0,180 R$/litro (vigente em Maio/2008) para zero (valor atual) significam um subsídio de cerca de R$ 4,5 bilhões por ano.



Fonte: MINFAZ, 2012

2. Causas e consequências

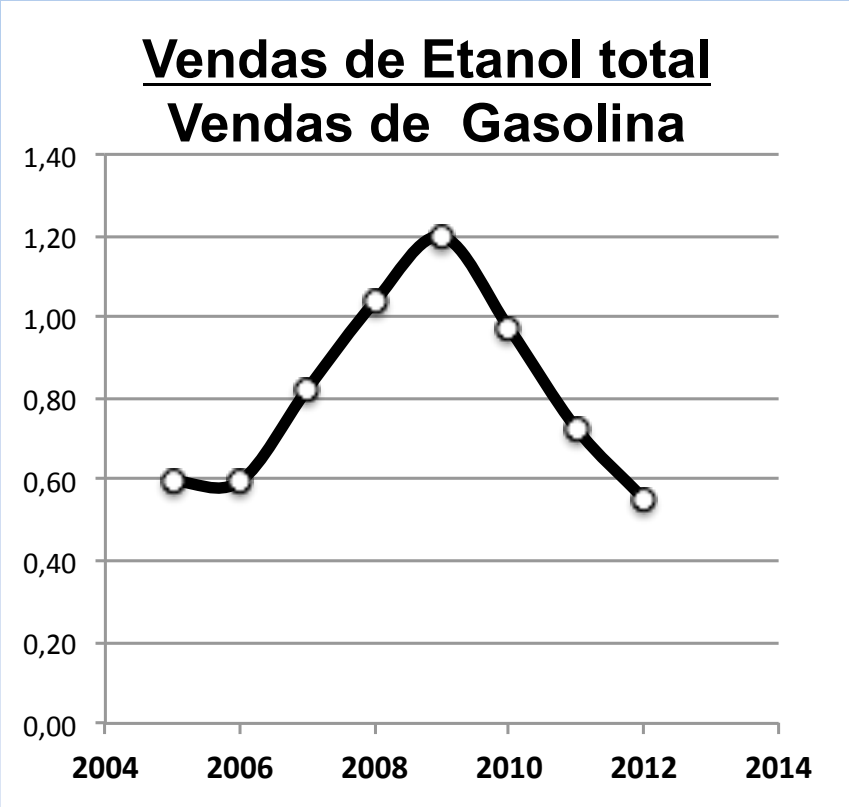
A redução de tributos sobre a gasolina foi adotada em outros países visando estabilizar seus preços em um contexto de custos crescentes, mas geralmente de modo limitado. Nos países da OCDE os tributos foram reduzidos em 7% entre 2001 e 2008.



Fonte: CEPAL, 2010

2. Causas e consequências

Síntese do retrocesso:



Fonte: ANP, 2012

Como sair dessa situação?

Como retomar a racionalidade?

3. Condições de contorno

O quadro atual é muito diferente do ínício do Pró-alcool.

Quadro legal vigente

- ✓ **extensa legislação, pouco consolidada**

Condicionantes na definição de políticas (1/2)

- ✓ **expansão da produção de etanol e de sua participação na produção da agroindústria**
- ✓ **expansão da frota com motores flexíveis (Unica, 2012)**
  - ***1.183 mil veículos flexíveis em 2005 (6% da frota)***
  - ***16.250 mil veículos flexíveis em Junho/2012 (54% da frota)***

3. Condições de contorno

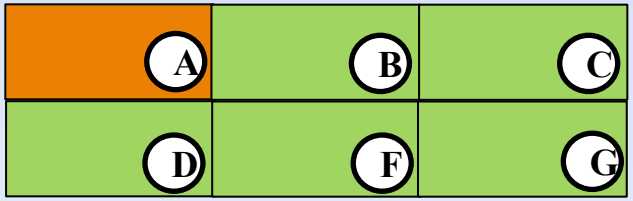
Quadro muito diferente do início do Pró-alcool.

Condicionantes na definição de políticas (2/2)

- ✓ mercado externo volátil e pouco definido
- ✓ inércia na retomada da expansão na produção de cana, uma cultura semi-perene

Cronograma de Produção Agrícola

Planted areas	year 1				year 2				year 3				year 4				year 5				year 6				year 7				year 8			
	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q
Seed area	P				C				C				C				C				C				C							
Area A					P					1C				2C				3C				4C				5C				R		
Area B									P					1C				2C				3C				4C				5C		
Area C													P					1C				2C				3C				4C		
Area D																	P					1C				2C				3C		
Area F																					P					1C				2C		
Area G																														1C		



Esquema de canaviais

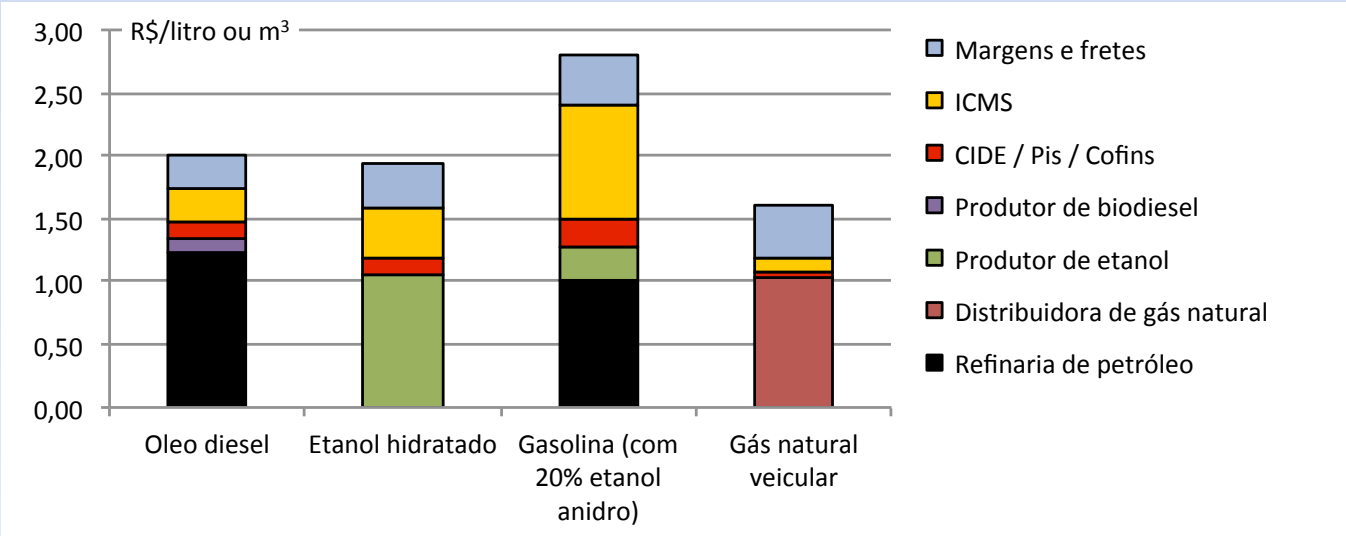
4. Política e regulação em bioenergia

Possíveis ações:

1) Rever o marco tributário

- ✓ **Relevância dos tributos como instrumento regulatório.**
- ✓ **A experiência brasileira na tributação dos combustíveis e sua motivação (CIDE e ICMS)**

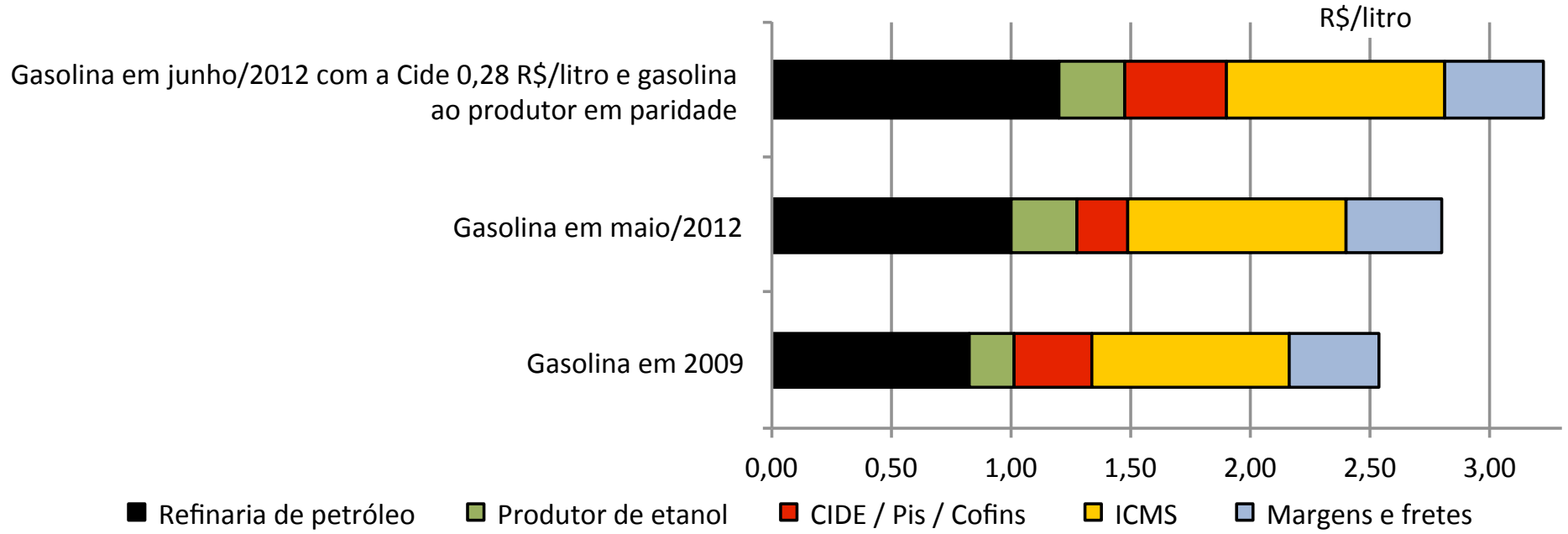
Composição do preço de combustíveis veiculares no Rio de Janeiro, maio de 2012



Fonte: Sindcomb (2012).

4. Política e regulação em bioenergia

Equilibrar o marco tributário é muito importante e pode melhorar em diversos sentidos a racionalidade do mercado energético.



<u>Importância da transparência das regras de formação de preços e a possibilidade de resgatar a função reguladora da CIDE</u>.

4. Política e regulação em bioenergia

Possíveis ações:

2) Uma lei para os biocombustíveis

*O Brasil utiliza biocombustíveis há décadas, mas ainda não possui uma **lei específica para ordenar esse mercado**, como acontece em muitos países que procuram replicar a experiência brasileira.*

Uma lei para a sustentabilidade dos biocombustíveis no Brasil, permitiria:

- ✓ **consolidar a legislação existente, tratando com equilíbrio vetores energéticos similares.**
- ✓ **definir o marco tributário para os biocombustíveis, considerando suas externalidades e estabelecendo os mecanismos de sustentação nos contextos de volatilidade, possivelmente mediante a arbitragem flexível dos tributos (CIDE).**
- ✓ **estimular e ordenar as atividades de Pesquisa e Desenvolvimento.**

5. Conclusões

- ✓ **São promissoras as perspectivas para a expansão da demanda de etanol no mercado mundial.**
- ✓ **O etanol de cana-de-açúcar, como produzido no Brasil, apresenta bons indicadores de sustentabilidade e potencial competitividade econômica.**
- ✓ **Há um quadro grave de crise e retração produtiva no setor sucroenergético brasileiro, cuja superação impõe que:**
  - **sejam implementadas políticas públicas que valorizem os biocombustíveis renováveis, em particular considerando seus aspectos sociais e ambientais.**
  - **se promova a transparência de regras na formação dos preços dos combustíveis.**

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The Nonsense of Biofuels

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Fossil fuels, like mineral oil, coal, and natural gas, are derived from the biomass of ancient times. As such, they are indirect products of photosynthesis. It is therefore appropriate to ask whether we can use currently available biomass and convert it into biofuels like biodiesel and biogas. Biohydrogen might be another option. Often one can read that biofuels are CO_2-neutral and therefore a weapon against global warming. Their production is also supposed to reduce the amount of petrol and natural gas to be imported into many countries, thus making them less dependent on energy import. In the following, I shall discuss the efficiencies of the processes required to produce biofuels, compare them with alternatives, draw the obvious conclusions, and present some visions.

The Efficiency of Photosynthesis

First it is necessary to discuss the efficiency of photosynthesis and to present some ideas on how to improve photosynthesis and therefore enhance biomass production. Photosynthesis comprises so-called light reactions and dark reactions. In the light reactions, the light is absorbed by the photosynthetic pigments and the energy is transferred to the reaction centers where the primary charge separation and a transmembrane transport of electrons takes place. Subsequent electron- and proton-transfer reactions lead to the synthesis of the universal biological energy carrier ATP from ADP and inorganic phosphate, and $NADP^+$ is reduced to NADPH. In the following dark reactions, NADPH and ATP are used to take carbon dioxide from the atmosphere and use it for the synthesis of carbohydrates.

The production of biofuels constitutes an extremely inefficient land use

The photosynthetic pigments of plants can only absorb and use 47% (related to energy) of the light of the sun ("photosynthetic active radiation"). Green light, UV, and IR irradiation are not used. In theory, 8 photons are required to reduce 2 molecules of $NADP^+$ to NADPH, in reality, 9.4 photons are found to be necessary for this purpose. Knowing the average energy of the photons and the energy stored in the form of NADPH, it is easy to calculate that only 11.8% of the energy of sunlight is stored in the form of NADPH. This value then also will be close to the upper limit for the efficiency of the photosynthetic production of biohydrogen.

Photosynthesis is most efficient at low light intensities. It is already saturated at 20% of full sunlight and 80% of the light is not used. The limitations are most likely caused by the electron flow through the photosynthetic reaction centers. In addition, high light intensities lead to photodamage of a central protein subunit of the photosynthetic apparatus: plants repair their photosystem II reaction center by exchanging the D1 protein three times per hour. 3.5 billion years of evolution have not been long enough to develop a mechanism for preventing the photodamage.

The dark reactions are limited by an insufficient discrimination between CO_2 and O_2 by the enzyme RuBisCO, which inserts CO_2 into ribulose-1,5-bisphosphate. One third of the energy of the absorbed photons is believed to be required to remove the product of the O_2 insertion, 2-phosphoglycolate. The second limitation is caused by the fact that photosynthesis depends on the availability of sufficient amounts of water, a condition that is not met during much of the day.

As a result of the limitations described above, 4.5% is considered as the upper limit of the photosynthetic efficiency of C_3 plants. However, in reality, values of only around 1% are observed, even for rapidly growing trees like poplars.

Biofuels

When the yields of biofuels per hectare are known, one can easily calculate how much of the energy of the sunlight is stored in the biofuels. For German "biodiesel" which is based on rapeseed, it is less than 0.1%, for bioethanol less than 0.2%, and for biogas around 0.3%. However, these values even do not take into account that more than 50% of the energy stored in the biofuel had to be invested in order to obtain the biomass (for producing fertilizers and pesticides, for ploughing the fields, for transport) and the chemical conversion into the respective biofuel. This energy normally is derived from fossil fuels. The produc-

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