http://bioenfapesp.org

FAPESP Bioenergy Research

BIOEN

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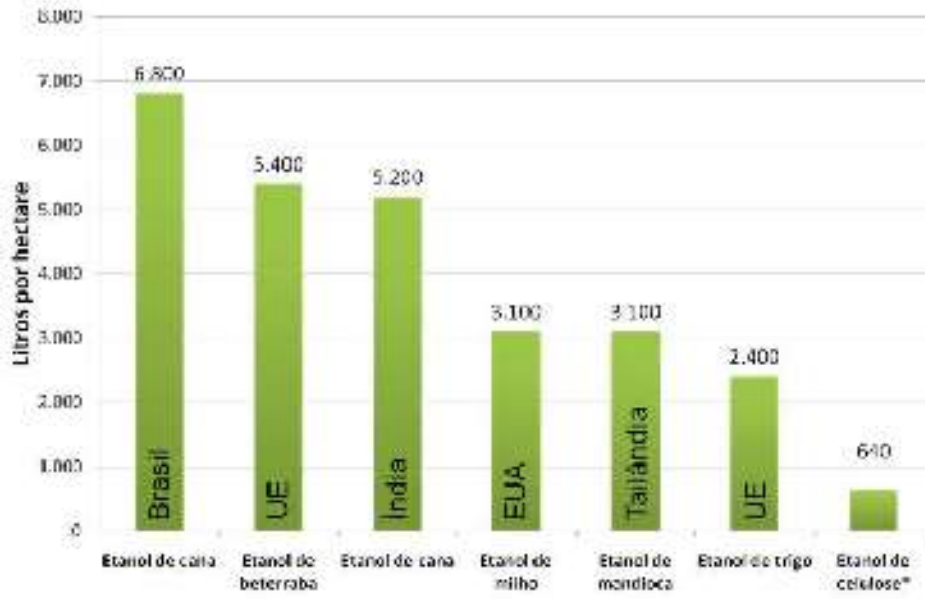
Energy Crops: a new Green Revolution

Designing crops for energy production

- High yield and fast growth crop
- Able to produce under short growing seasons
- Tolerant to periodic drought and low temperatures
- Low nutrient inputs requirements
- Relatively small energy inputs for growth and harvest
- Ability to grow in sub-prime agricultural lands
- Low cost of energy production from biomass
- Significantly positive energy balance
- Significant GHG reduction

Total brazilian bioethanol production for 2010/11 is projected at 28.5 billion L

Total sugarcane production is estimated to be 664,33 million tons



664 million tons of sugarcane/year

54,6% (362,8 million tons) for ethanol
(20,14 billlion L hydrated and 8,4 billion L anyhidride)

45,4% (301,6 million tons) for sugar (38,7 million tons)

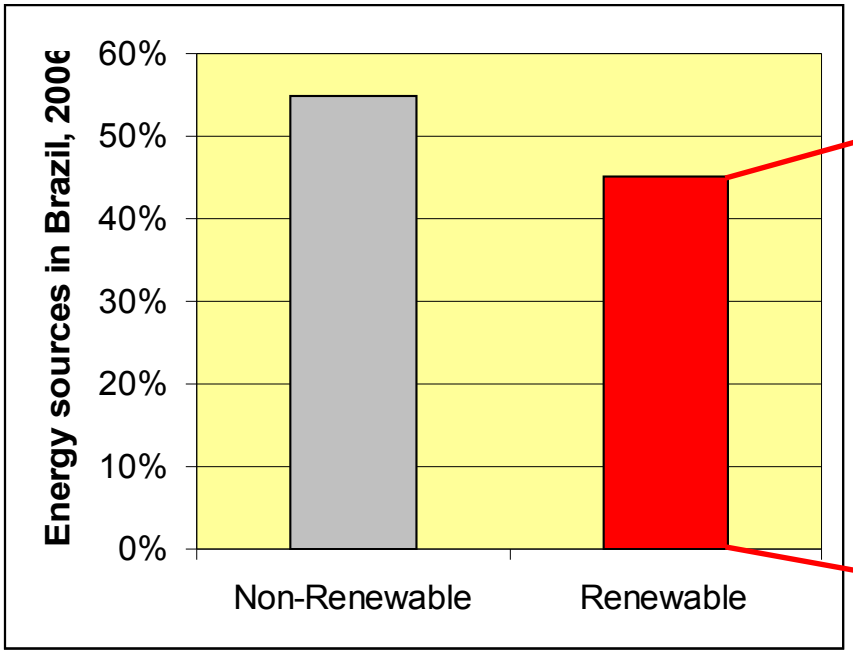
405 plants of which 157 are exclusive to ethanol

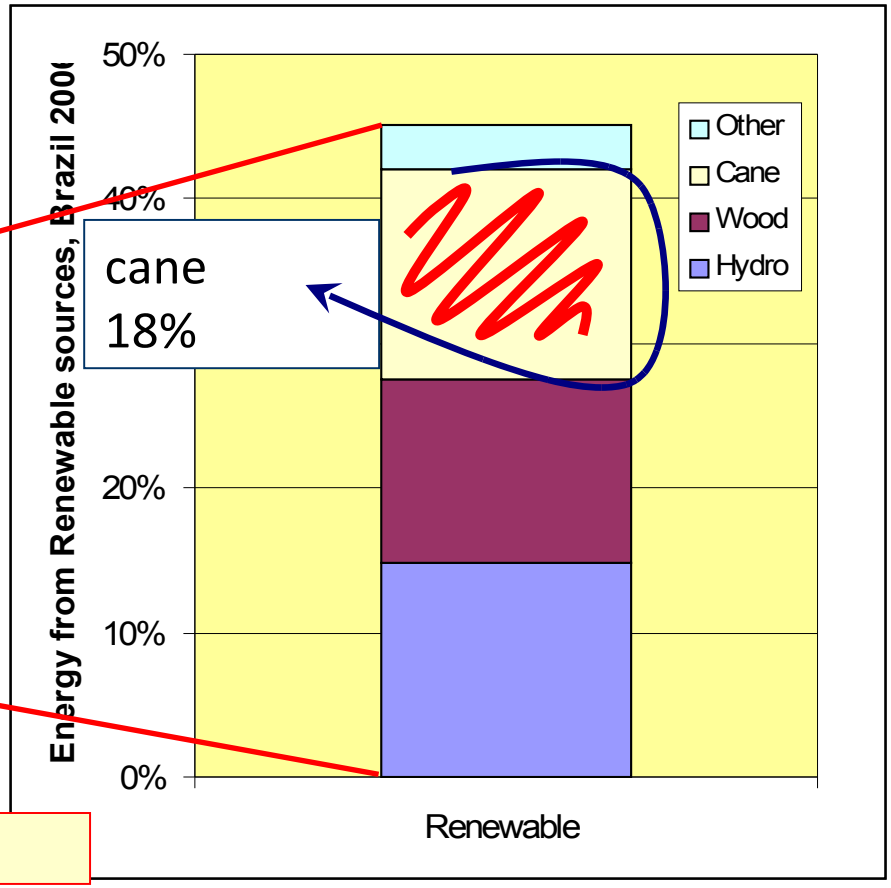
Sugarcane is the highest tonnage crop

Fast growth
In 12 months the plant will reach 4-5 meters with the extractable stems measuring 2-3 meter

Large amount of carbon partitioned into sucrose
(up to 42% of the stalk dry weight)

47% of Brazil's energy comes from renewable sources

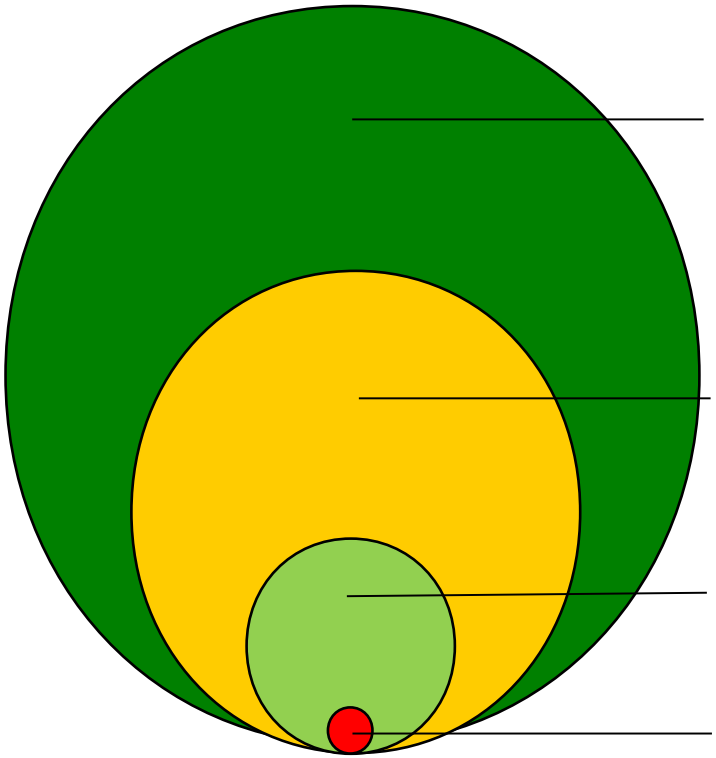




Renewables in Brazil: 47%; World: 12%; OECD: 7.6%

Source: MME-BEN (2007)

Sugarcane for ethanol uses 2% of agricultural area



Total country area (851 Mha, 100%)

Rural properties area (355 Mha, 42%)

Area used for agriculture (76.7 Mha, 9%)

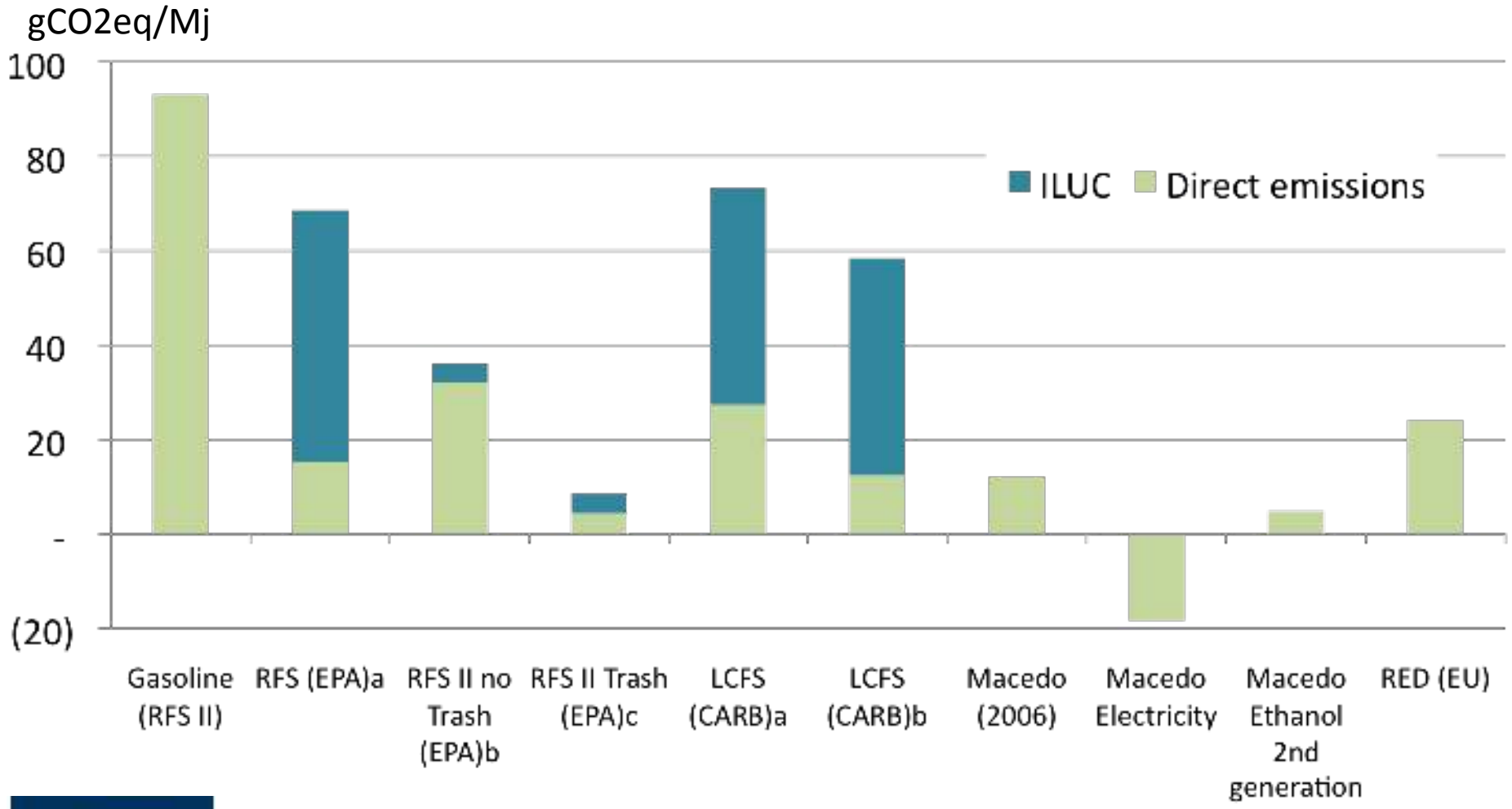
Area used for sugarcane for ethanol (3.4 Mha, 0.4%)

Pasture 200 Mha

Soya 22 Mha

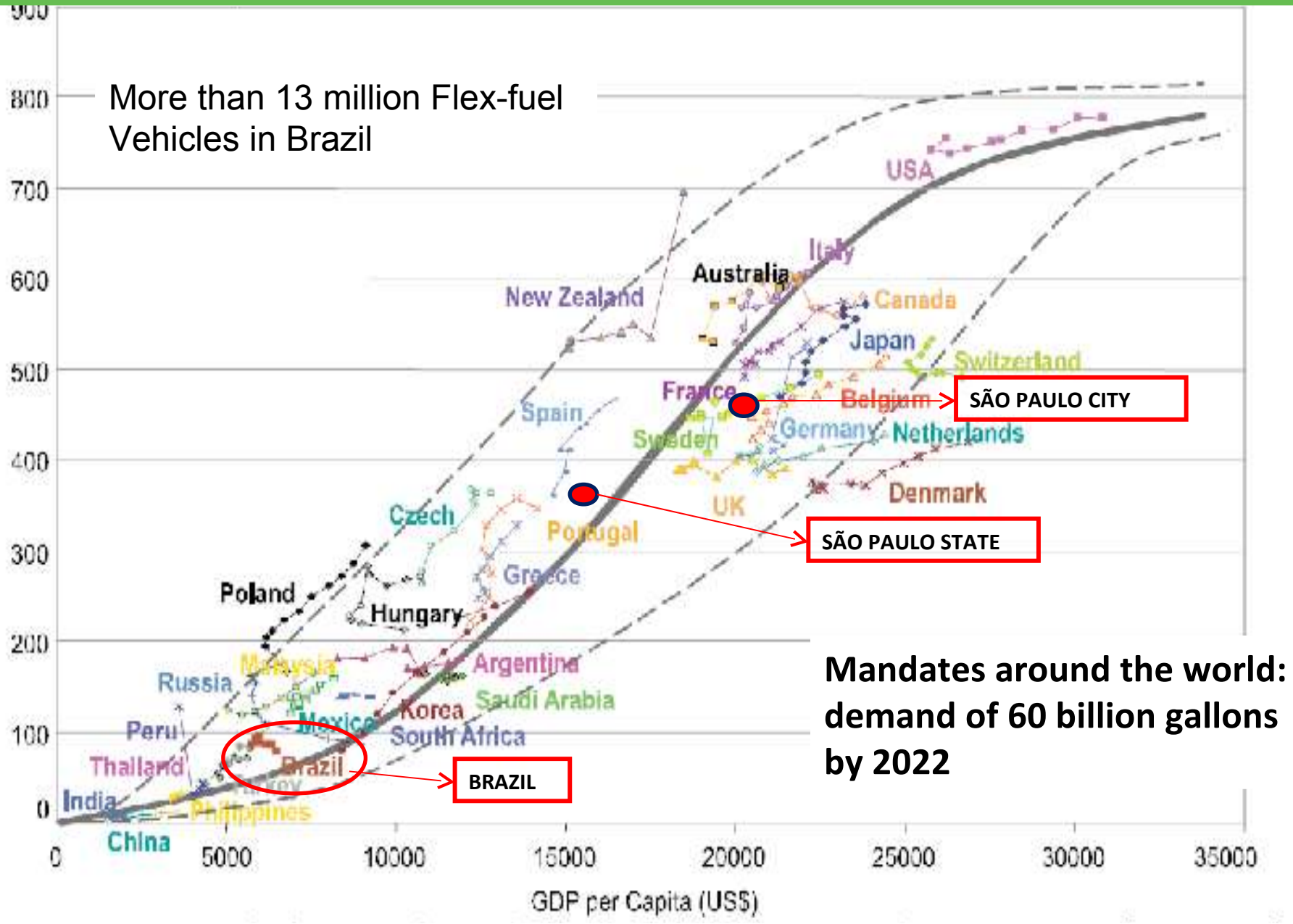
Source: Horta Nogueira e Seabra (2008)

80% reduction of GHG emissions using sugarcane ethanol



ICONE
Instituto de Estudos do Comércio e Negociações Internacionais

Brazilian bioethanol demand: 50 billion L to substitute 45% of otto cycle cars by 2020



Expanding sustainably

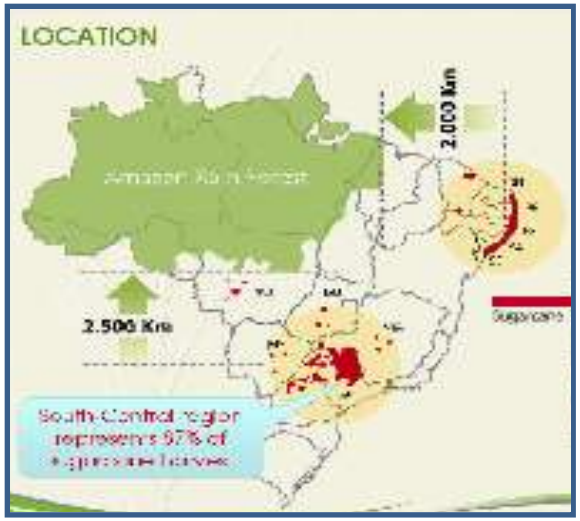
Southwest: dry winter
Marginal land, pastureland, and poor soils

- Drought resistance
- Crop breeding to new environments
- Revise nutritional needs and managing of fertilizers
- Recycle nutrients of crop and industry residues
- Land Use Change Models

South America
Central America
Africa: 0.43 GHa @ 10kL/Ha.yr

→ **4,300GL**

2050: Available land for biofuels
(Doornbosch and Steenblik, 2007)



FAPESP Bioenergy Research Program BIOEN

Fundamental knowledge and new technologies for a bio-based society

- Academic Basic and Applied Research (US$ 30 million)
  59 grants, 300 brazilian researchers, 61 foreign researchers from 12 countries
  – Regular, Theme and Young Investigator Awards
  Open to foreign scientists who want to come to Brazil

- State of São Paulo Bioenergy Research Center (US$ 90 million)

- International partnerships
  United States, United Kingdom and The Netherlands
  (Oak Ridge National Laboratories, UKRC, BBSRC, BE-Basic)

- Innovation Technology, Joint industry-university research (5 years) (US$ 83 million)

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
ETH	Agricultural practices	US$ 5,000,000
Microsoft	Computational development	US$ 500,000

BIOEN DIVISIONS

BIOMASS
Contribute with knowledge and technologies for Sugarcane Improvement
Enable a Systems Biology approach for Biofuel Crops

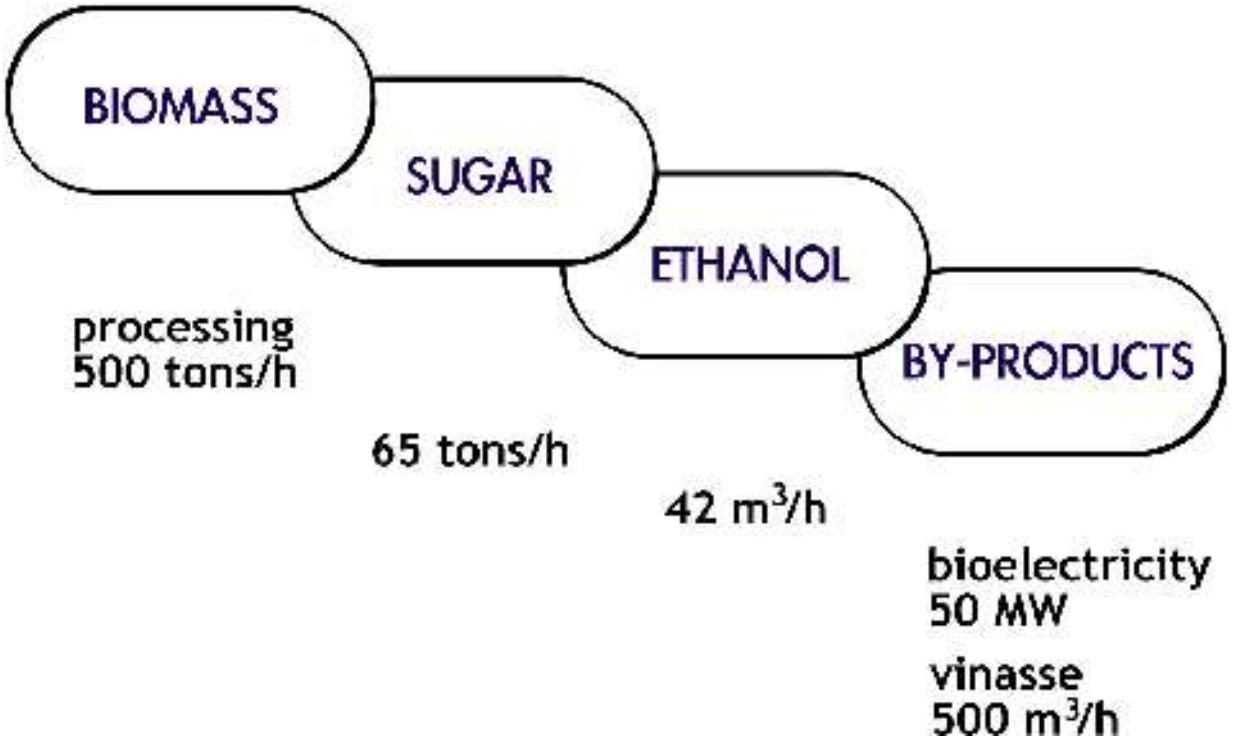
BIOFUEL TECHNOLOGIES
Increasing productivity (amount of ethanol by sugarcane ton), energy saving, water saving and minimizing environmental impacts

ENGINES
Flex-fuel engines with increased performance, durability and decreased consumption, pollutant emissions

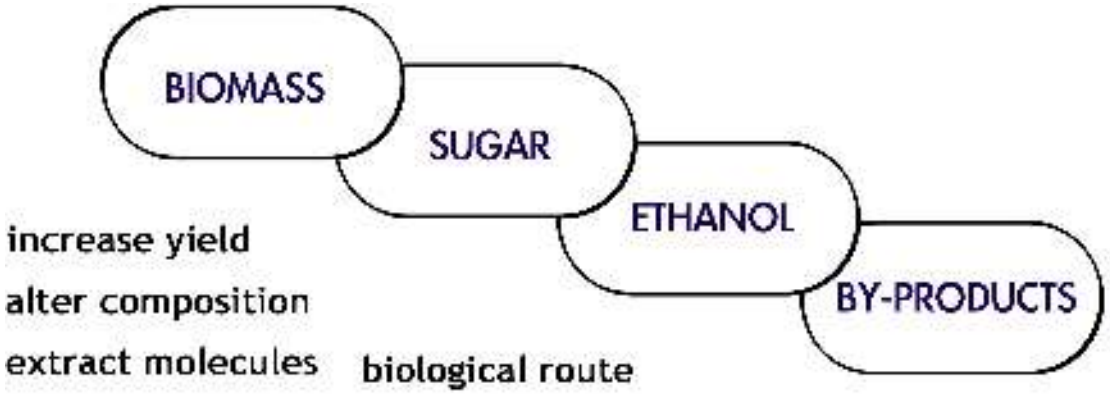
BIOREFINERY
Complete substitution of fossil fuel derived compounds
Sugar chemistry, alcohol chemistry and oil chemistry for intermediate chemical production and as a petrochemistry substitute

IMPACTS
Studies to consolidate sugarcane ethanol as the leading technology path to ethanol and derivatives production
Social, economic and environmental impact studies

Sugarcane Agro-industry



Research to expand the industrial model



increase yield
alter composition
extract molecules
transform

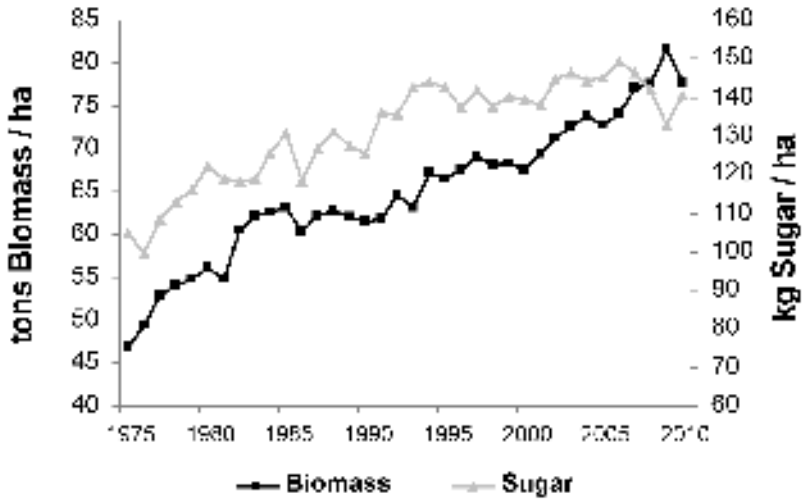
biological route
ethanol
butanol
lactic acid

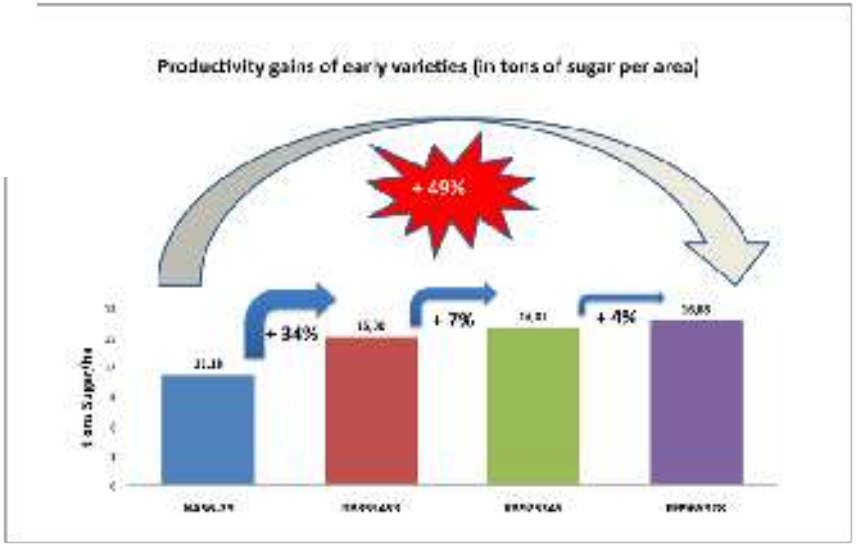
chemical route
biokerosene
green ethane
bulk chemicals
engines

bioelectricity
bagasse
straw
CO_2
cellulosic ethanol
algae biodiesel
syngas
biogas
vinasse

Sugarcane: the highest tonnage crop

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





Theoretical maximum: 380 tons/ha
Current average: 75 tons/ha

Waclawovski et al., 2010; Costa et al., 2011

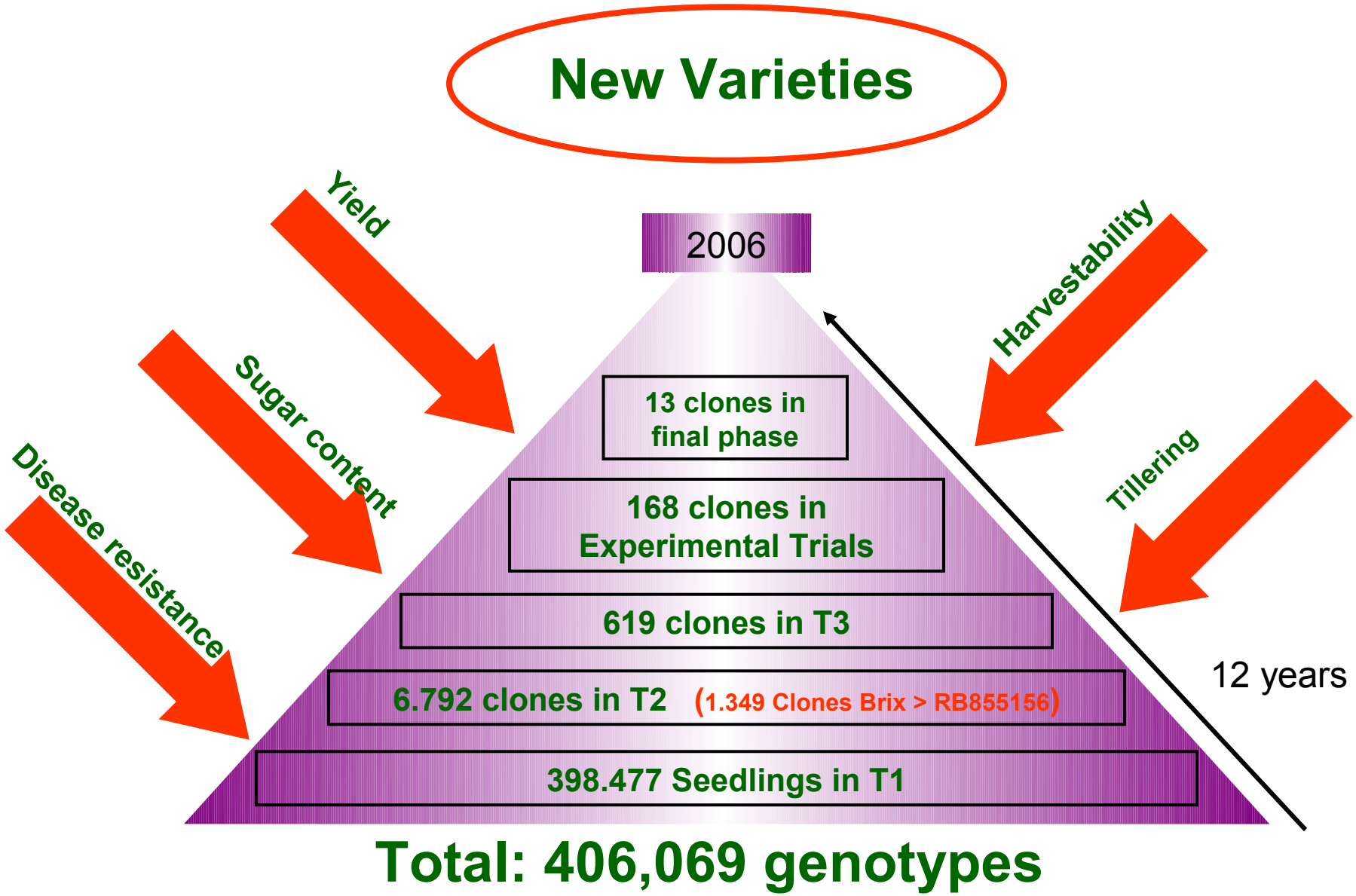
BIOMASS DIVISION

Improvement of Biomass

Agronomy, Breeding, Biotechnology

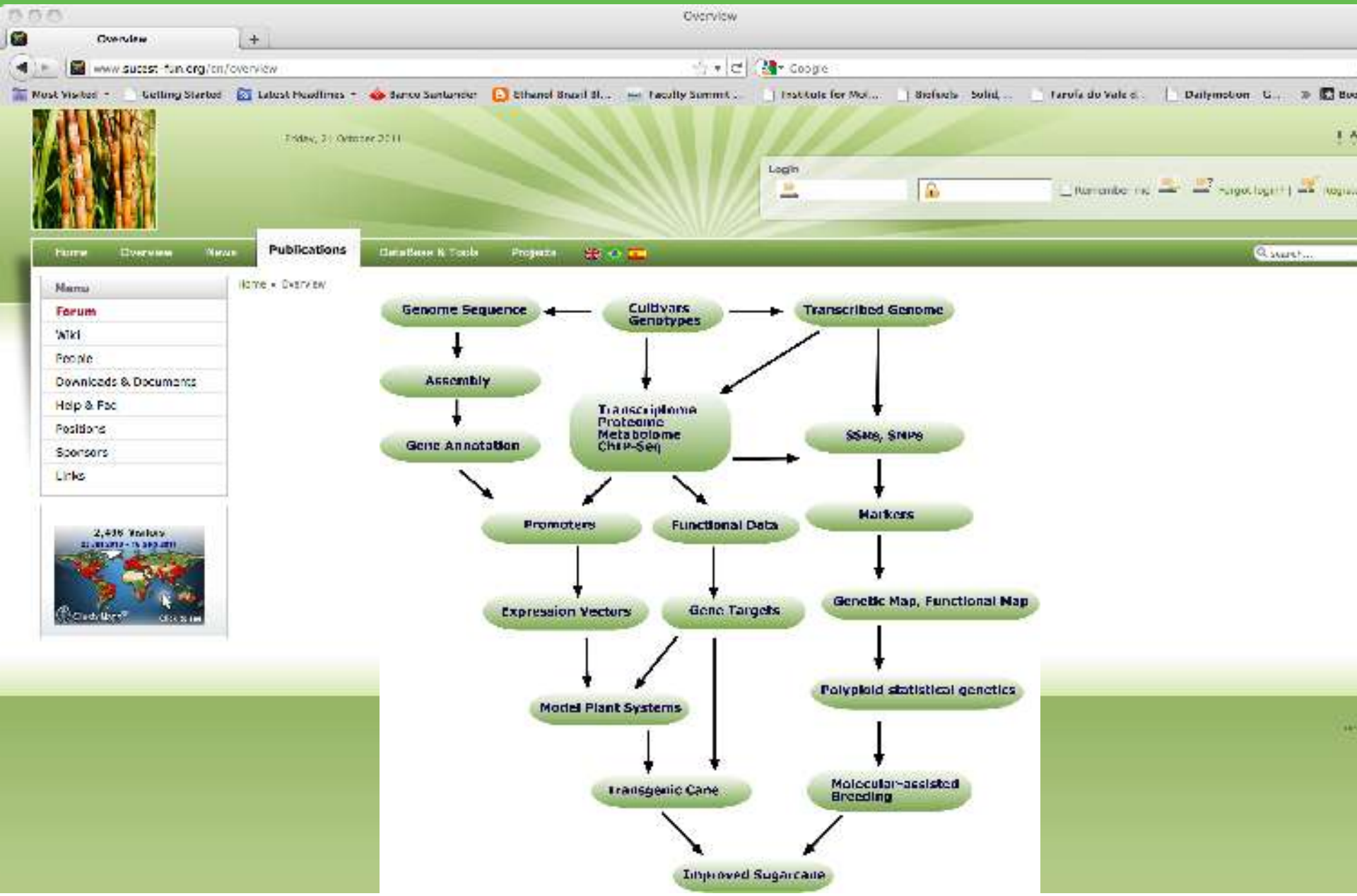
Identify new paths to genetically manipulate the energy metabolism of cultivated plants, creating new biofuel and bio-based chemical alternatives

On average, one variety can be obtained for each 250 thousand seedlings



Total: 406,069 genotypes

Integrating efforts: http://sucest-fun.org



BIOFUEL TECHNOLOGIES DIVISION

Engineering, processing and equipment design

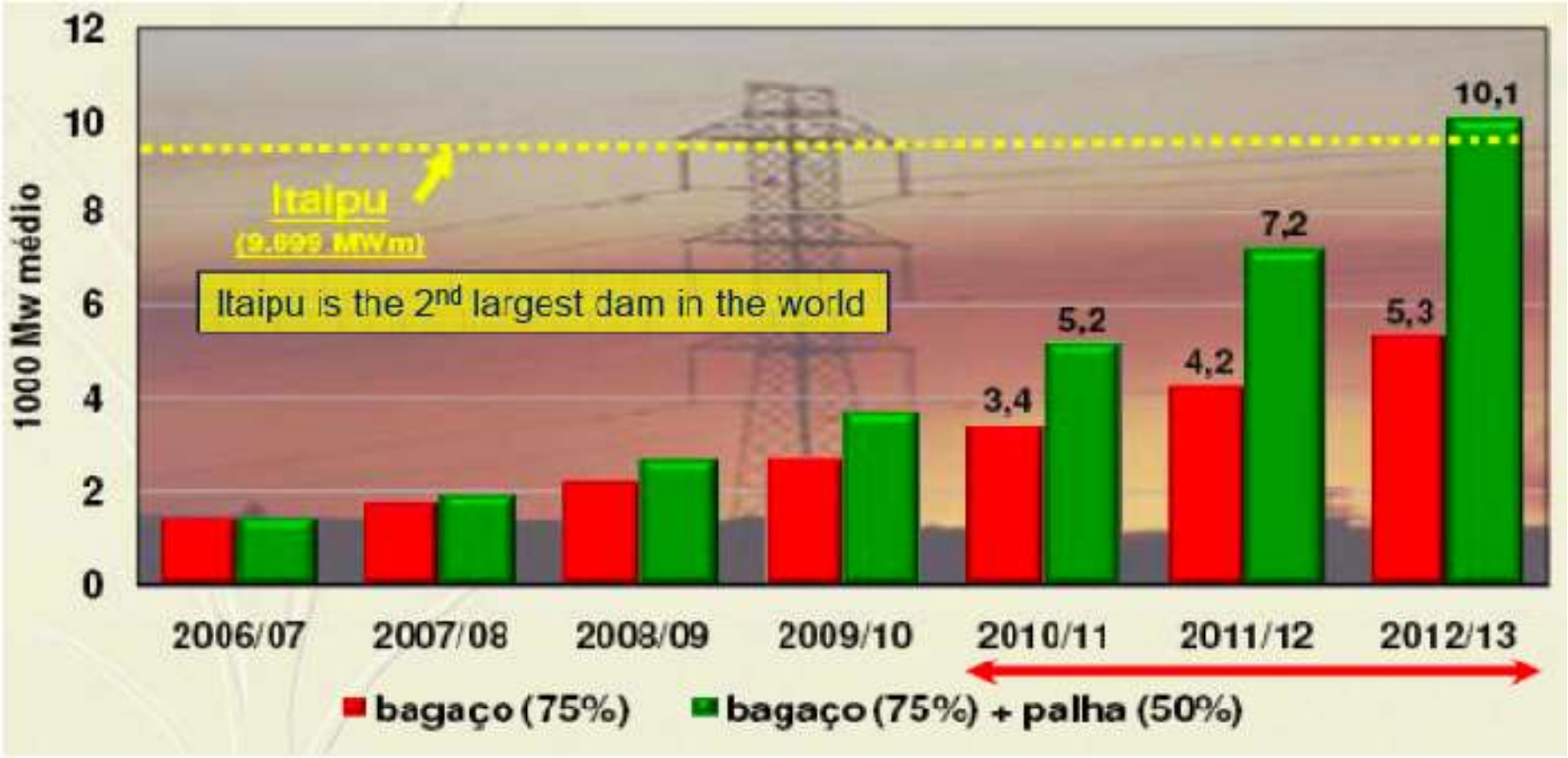
Bottlenecks of biofuel production

Sucrose to Butanol (extractive fermentation)

Ethanol to Biokerosene (new chemical route, high purity)

Cellulosic ethanol (lower solids and reduced incubation time)

It is possible to have bagasse surplus to produce electricity and ethanol



Co-generation in 2009/10 = 1.800 MW (3% of electricity matrix)

In 2020 = 14.000 MW (14% equals 1 Itaipu)

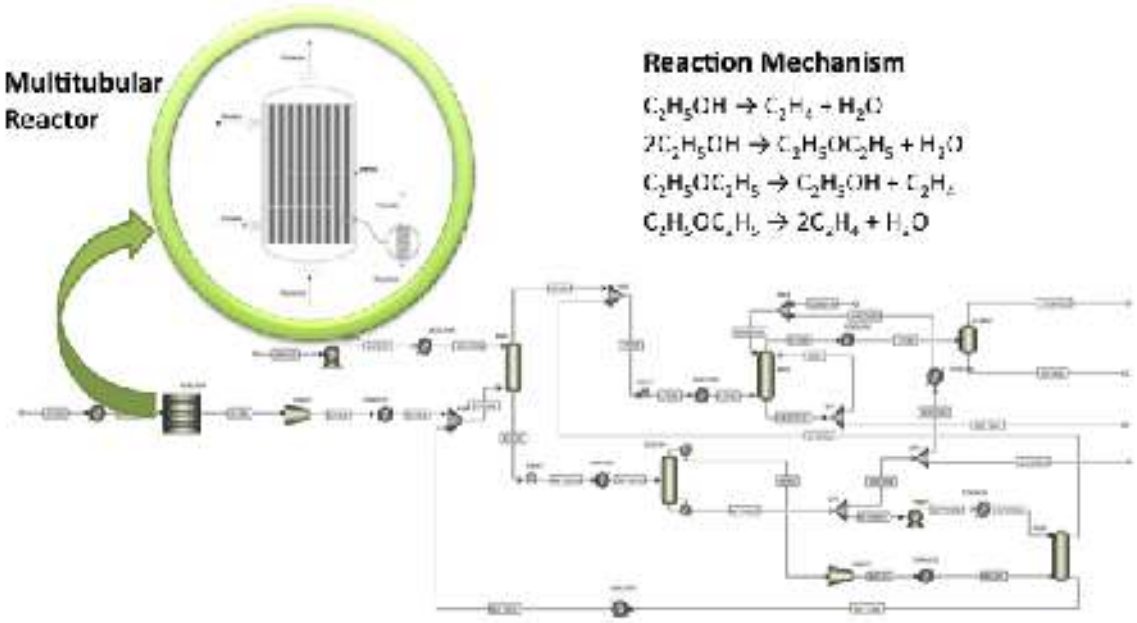
Investments of R$ 45 billion until 2015 on Co-generation (boilers from 21 bar to 92 bar)

BIOREFINERIES DIVISION

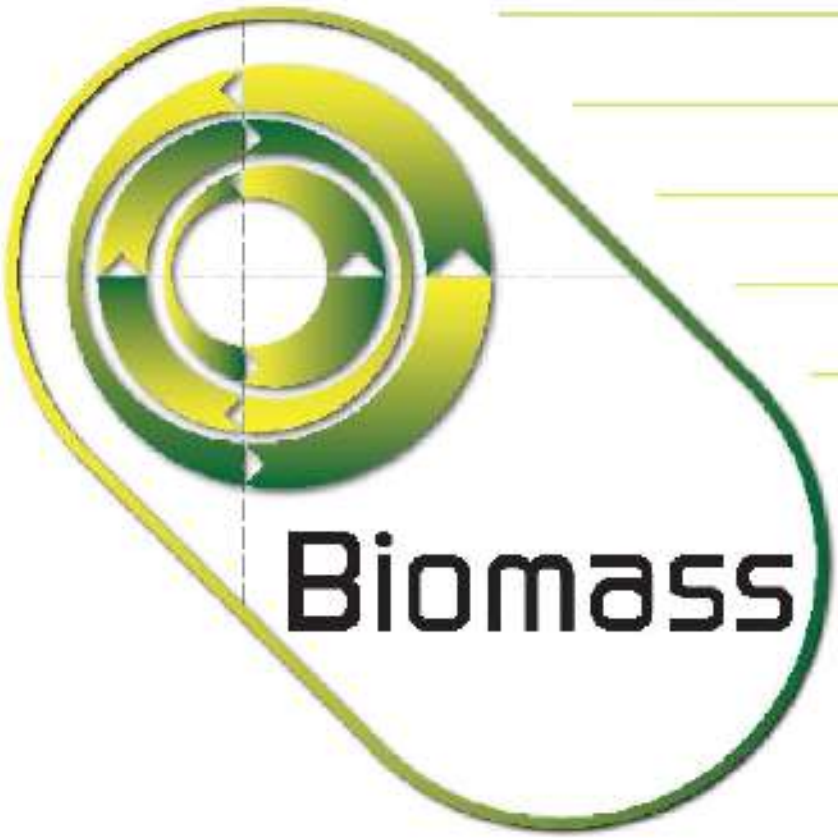
Integrated bioethanol, **biogas** and electricity production (double energy output)

Zero carbon emission biorefinery system (consorted bioethanol-biodiesel-biokerosene production)

Bio-based chemicals using a synthetic biology approach (production of lactic acid isomers from sucrose, $$$, 190,000 added value)



Products from ethanol via acetaldehyde and ethylene route (Green Ethane Process to 98.9% purity)



Genome
Transcriptome
Proteome
Metabolome
Cell Machinery
Metabolic Engineering
Breeding
Process Modeling
Simulation
Biorefinery
Synthetic Chemistry
Bioprospection
Automation, Robotics
Evolution of microorganisms
Design of proteins
Expression Systems

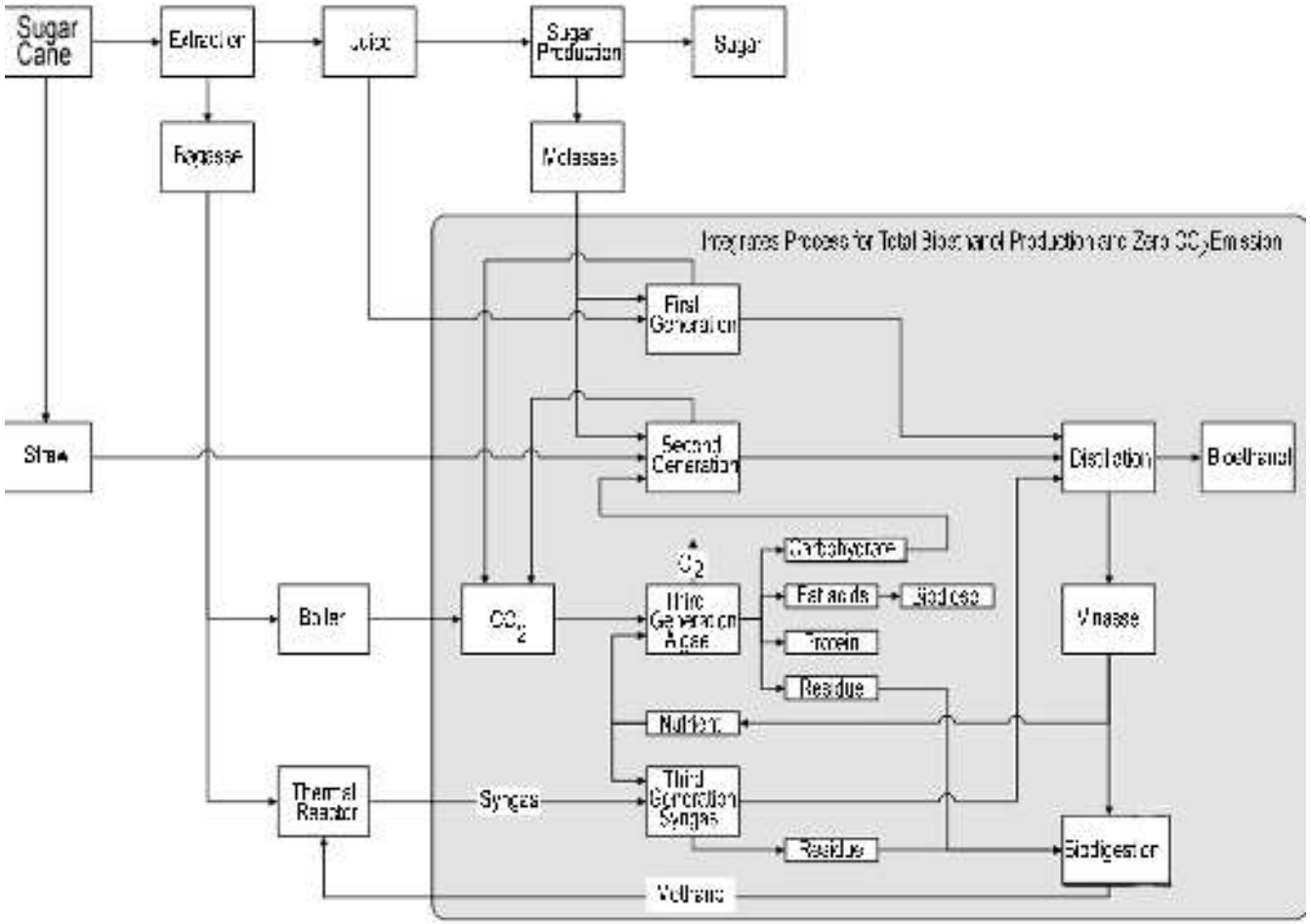
Biomass Systems and Synthetic Biology Center

Institute of Chemistry
Institute of Biosciences
Institute of Mathematics and Statistics
Institute o Biomedical Sciences
Engineering School

State of São Paulo
Bioenergy Research Center
NAP Bioenergy and Sustainability
University of São Paulo

The Bio: everything is coming from the farm

How do we get to zero carbon emissions?



Rubens Maciel (Unicamp)

ENGINES DIVISION

Research to consolidate ethanol as the renewable substitute for gasoline on a short to medium term (10 to 20 years), with the evolution of internal combustion engines, and on a long term with fuel cells.

Flex-fuel engines with increased performance, durability, less fuel consumption and less pollutant emissions

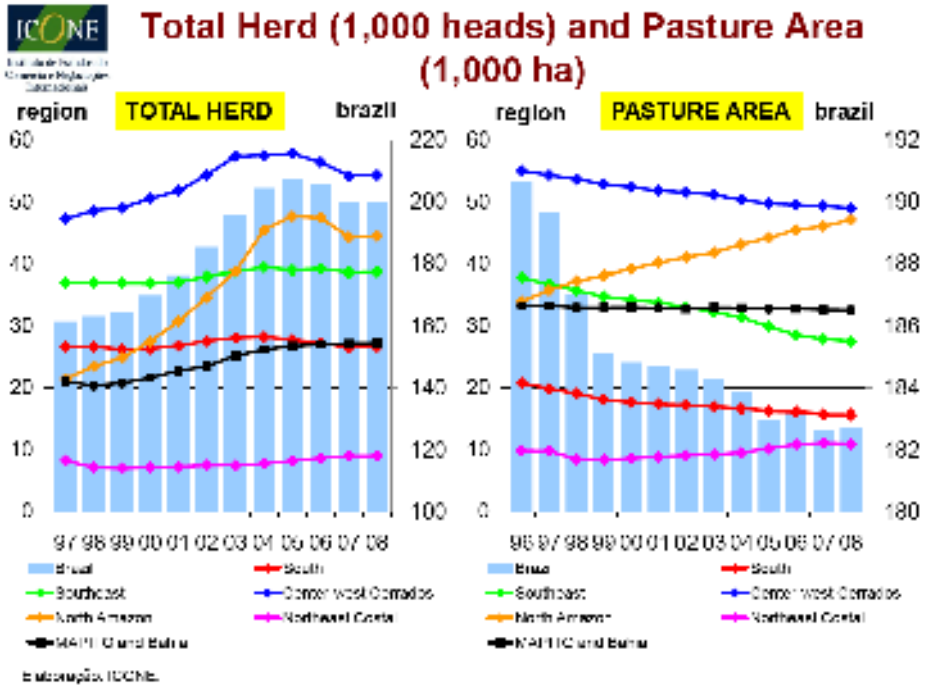
Efficiency of a Flex-fuel Vehicle is 30%

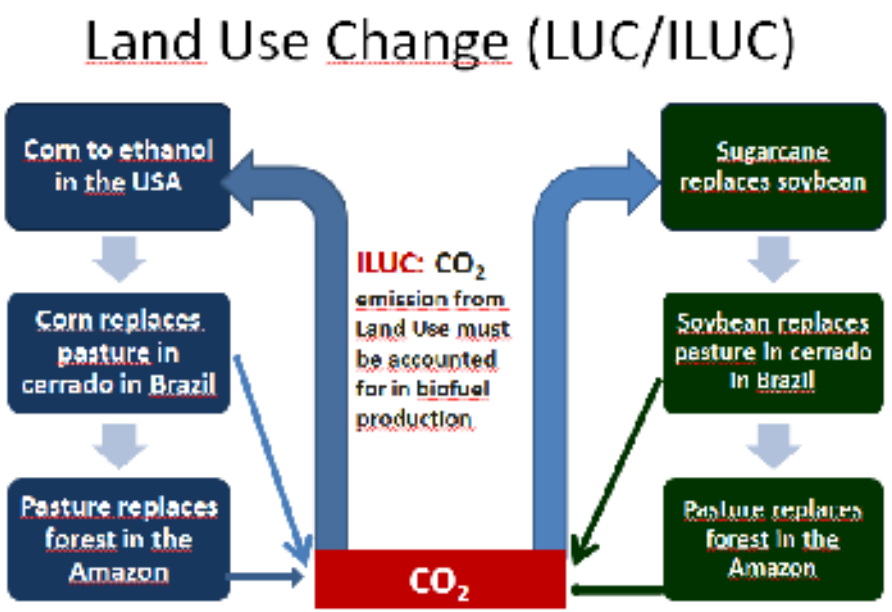
Design new more adequate fuels

Cold-starting problem

Decrease fuel consumption and CO_2 emissions

Good for People, Planet and Profit





Economic Model for Food vs. Fuel vs. Land vs. Biodiversity

IMPACTS DIVISION

Ethanol as a global strategic fuel

Land use changes
GHG emissions
Biomass and soil carbon stocks
Water use
Biodiversity
Regional income generation
Job creation and migration
Integrating tools

Studies to consolidate sugarcane ethanol as the leading technology path to ethanol and derivatives production

ScienceDirect

Biotechnology

Sugarcane improvement: how far can we go?

Plant Biotechnology Journal

Review article

Sugarcane for bioenergy production: an assessment of yield and regulation of sucrose content

RESEARCH ARTICLE Open Access

Identification and expression analysis of microRNAs and targets in the biofuel crop sugarcane

The Biotechnology Roadmap for Sugarcane Improvement

BMC Genomics

Open Access

Sugarcane genes associated with sucrose content

Characterization of new polymorphic functional markers for sugarcane

SHORT REPORT Open Access

Functional markers for gene mapping and genetic diversity studies in sugarcane

Bioresource Technology

Simulation of integrated first and second generation bioethanol production from sugarcane: comparison between different biomass pretreatment methods

Applied Biochemistry Biotechnology

DOI 10.1007/s12010-009-8824-0

Production of Lactic Acid from Sucrose: Strain Selection, Fermentation, and Kinetic Modeling

Bernnia H. Lunelli · Rafael R. Andrade · Daniel I. P. Atala · Maria Regina Wolf Maciel · Francisco Maugeri Filho · Rubens Maciel Filho

ARTICLE

Bioproduction of Butanol in Bioreactors: New Insights From Simultaneous In Situ Butanol Recovery to Eliminate Product Toxicity

BIOEN

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Biofuels and land-use changes: searching for the right model

nature

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OUTLOOK

Perspective: Lessons from Brazil

Nature 474, 320 (23 June 2011) doi:10.1038/474320a

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