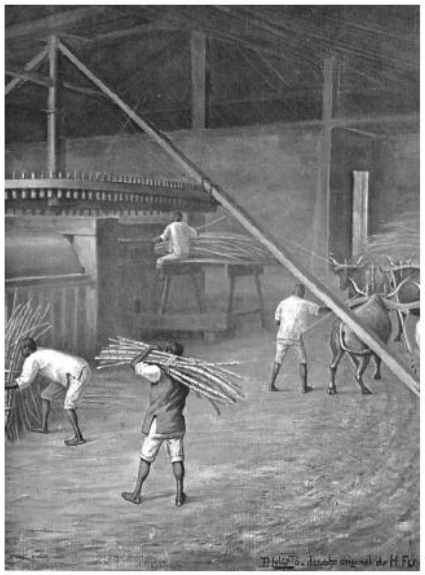
From ancient sugar factories to modern bio-refineries



BIO-ETHANOL

Internal Driving-forces:

Pró-álcool (1975);

•Flex fuel vehicles.

External driving-forces:

•Global warming;

•Ethanol demand in 20 years estimated in 200 bilion liters year.

SUGAR

BIO-ENERGY

BIO-FERTILIZER

BIO-BYPRODUTOS

Biofuel

The energy from sugar cane

Consumption of process steam depends on proportion of sugar and ethanol produced:

•Ethanol plant →260-270 kg/TC

•Sugar (50%) + ethanol (50%) →300 - 340 kg/TC

•1 TC = 240 kg de bagasse (50% humidity) = 528 kg of steam + 240 kg of leaves.

Cane processing units have surplus of energy:

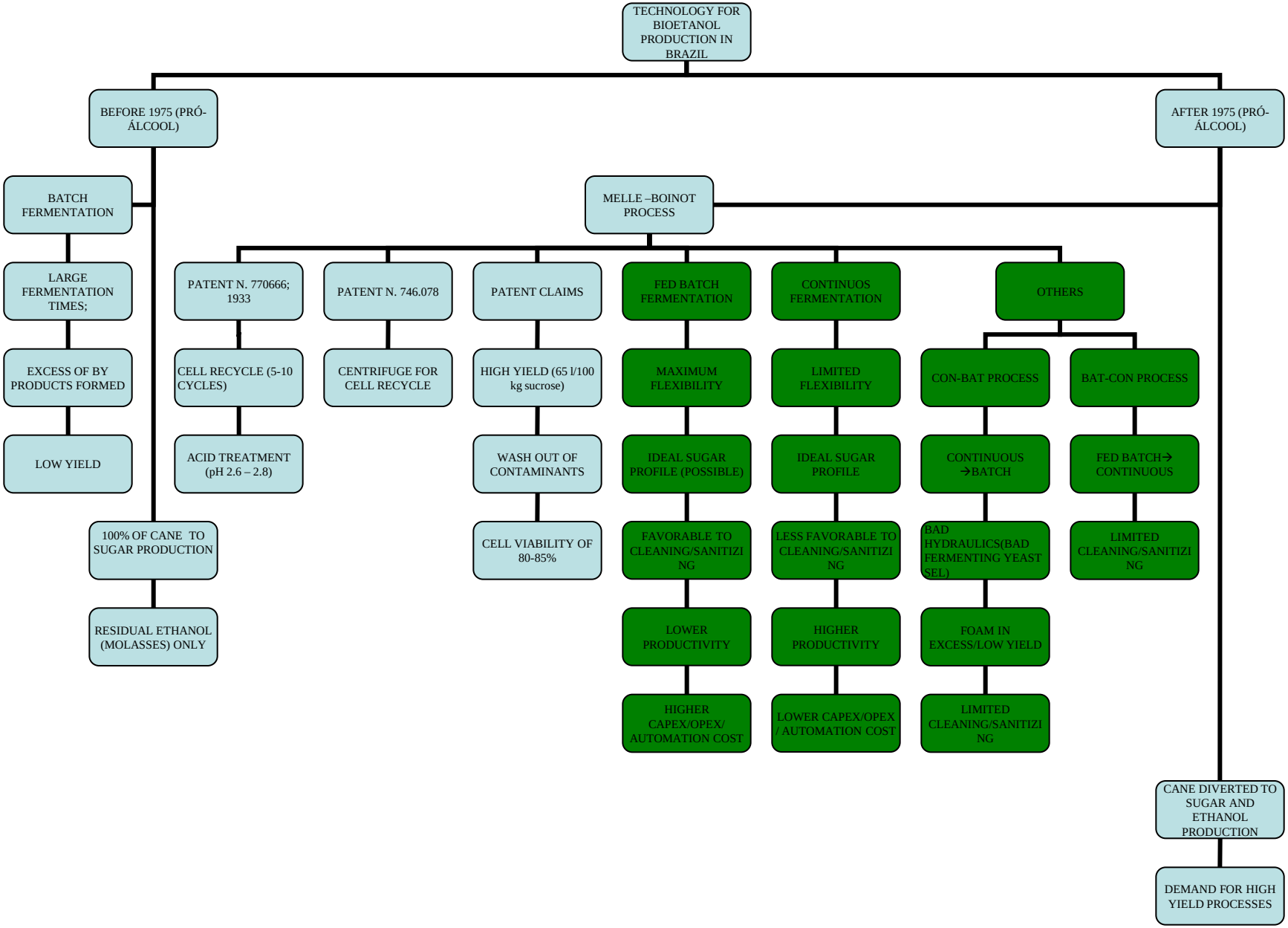
2.000MW (2007) with estimated potential of 20.000MW, equivalent to two ITAIPUS.

Composição média da cana-de-açúcar	
Composition	(%) m/m.
Water	65-75
Sugars	11-18
Fiber	8-14
Solubles	12-23

Environmental impact (Macedo, 2002)

$$\frac{renewableEenergy_{output}}{fossilEnergy_{input}} = 8.3$$

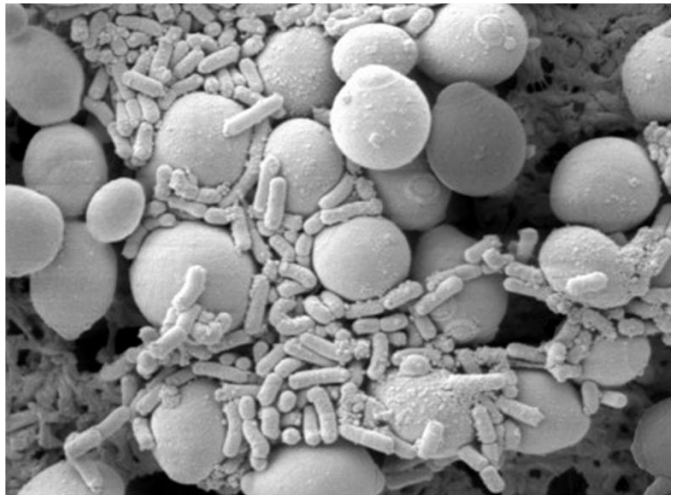
Technology of bioethanol production in Brazil - overview

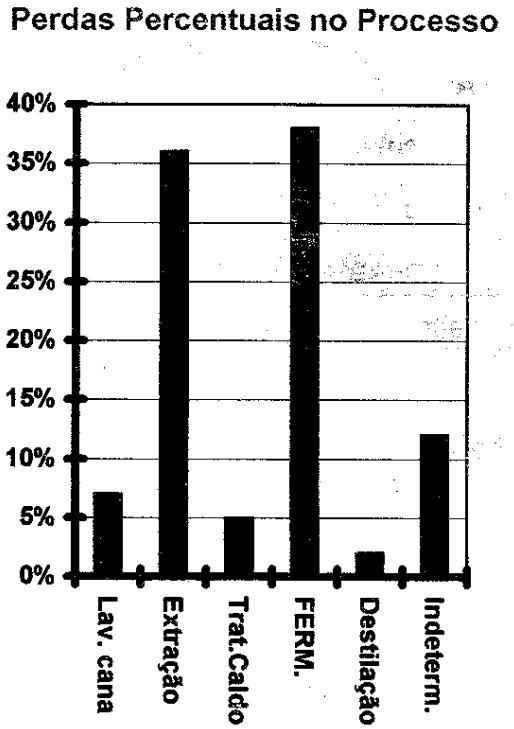


Technology of bioethanol production in Brazil - overview

Main process characteristics:

- Lack of sanitary criteria in the design;
- Mash w/ low ethanol titre (8.5% v/v, avg);
- Presence of contaminants & insolubles;
- High volume of vinasse produced (10-15 l/l);
- Energy consumption in distillation.
- Intensive use of sulfuric acid and human antibiotics or chemically related to (260 t in 2008 crop season).

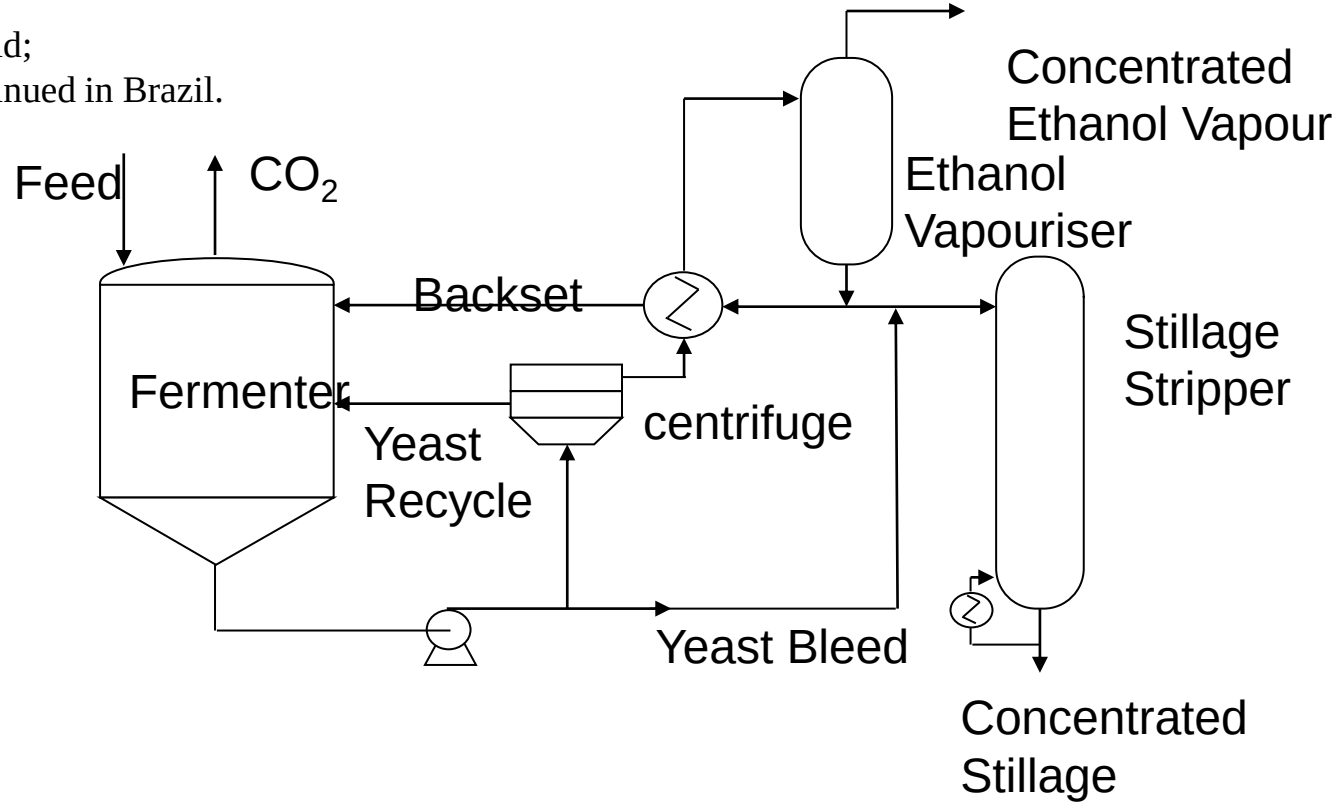




CTC (1996)

Biostil/Biostil 2000 fermentation process (CHEMATUR)

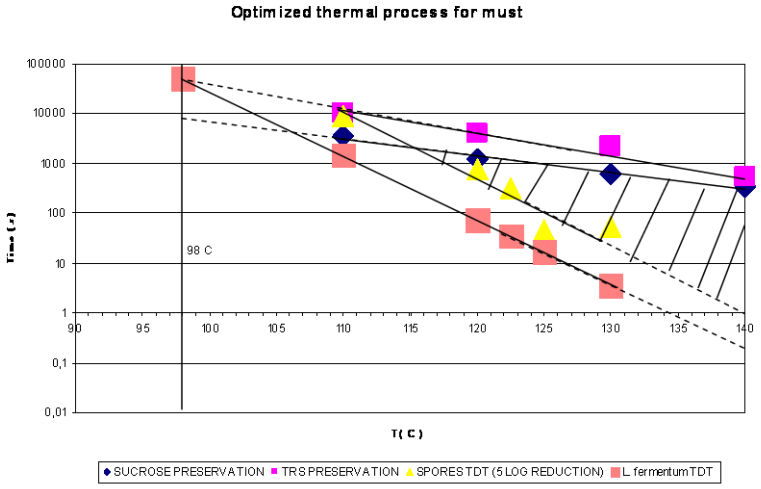
- Vinasse recycle to fermentation;
- Fermentation under high osmotic pressure by salts (non sugars);
- 3 l/l;
- Low yield;
- Descontinued in Brazil.



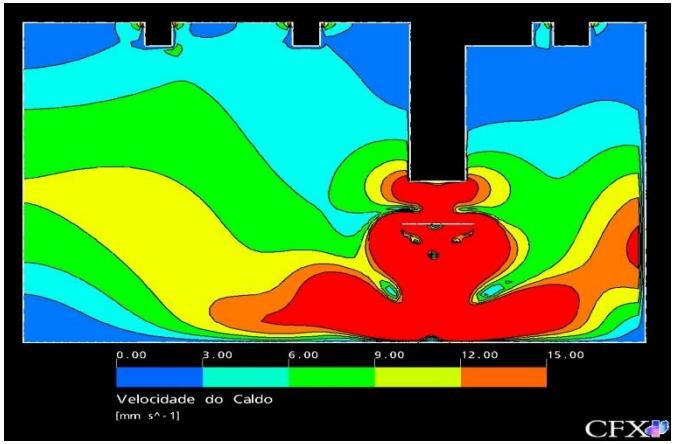
Technology of bioethanol production in Brazil - overview

- 1990's: Focus on biocatalysts/fermentation modelling (Andrietta *et. al*., 1994, 1995,1999)
  - Studies on populational dynamics in fermentation carried out by CTCopersucar spread the use of selected and more adaptaded yest strains.
  - Methodology to asses fermentative capability of yeasts based on kinetics, productivity and yield parameters (Andrietta *et. al*.1999).

  - 2000's: Focus on contamination (Nolasco Junior, 2005,2009)
  - Studies comprising technologies to manage contamination preventively:
    - Design and validation of an optimal thermal process to must based on thermal degradation kinetics of sugars and heat resistance of spores of *B. stearothermophilus.*
    - Contamination modelling in fermentation through operational parameters.
    - Design of must treatment process to ethanol production (computational fluid dynamics)
    - Design of fermentation process based on sanitary criteria (bioprocess)



$$B_v = f(R_c, \mu_{máxB}, B_m)$$



Technology of bioethanol production in Brazil - overview

•Antibiotic therapy

•Identical microbial ecology can be found in Brazilian sugar cane, US corn ethanol, beet and lignocellulosic compounds, the so called 2nd generation biofuel: gram positive bacteria from genera *Bacillus* e *Lactobacillus* (Klaushofer *et al.* 1998; Gallo e Canhos 1991; Skinner e Leathers, 2004; Klaushofer *et. al.*, 1998; Schell *et. al*., 2007).

•Resistance associated to continuous use of antimicrobials or Antibiotic Pressue.

•US: 25000t/a, being 50% to human and 50% in non human use (agriculture, veterinary, acquaculture, animal feed).

•Biofuel worldwide increasing list of non-human use of antibiotics.

•Antibiotics are the scope of a current and future war: that of antibiotics resistance that will be lost if there is not a global awareness about the problem adopting strategies to defeat it (Wannmacher 2004).

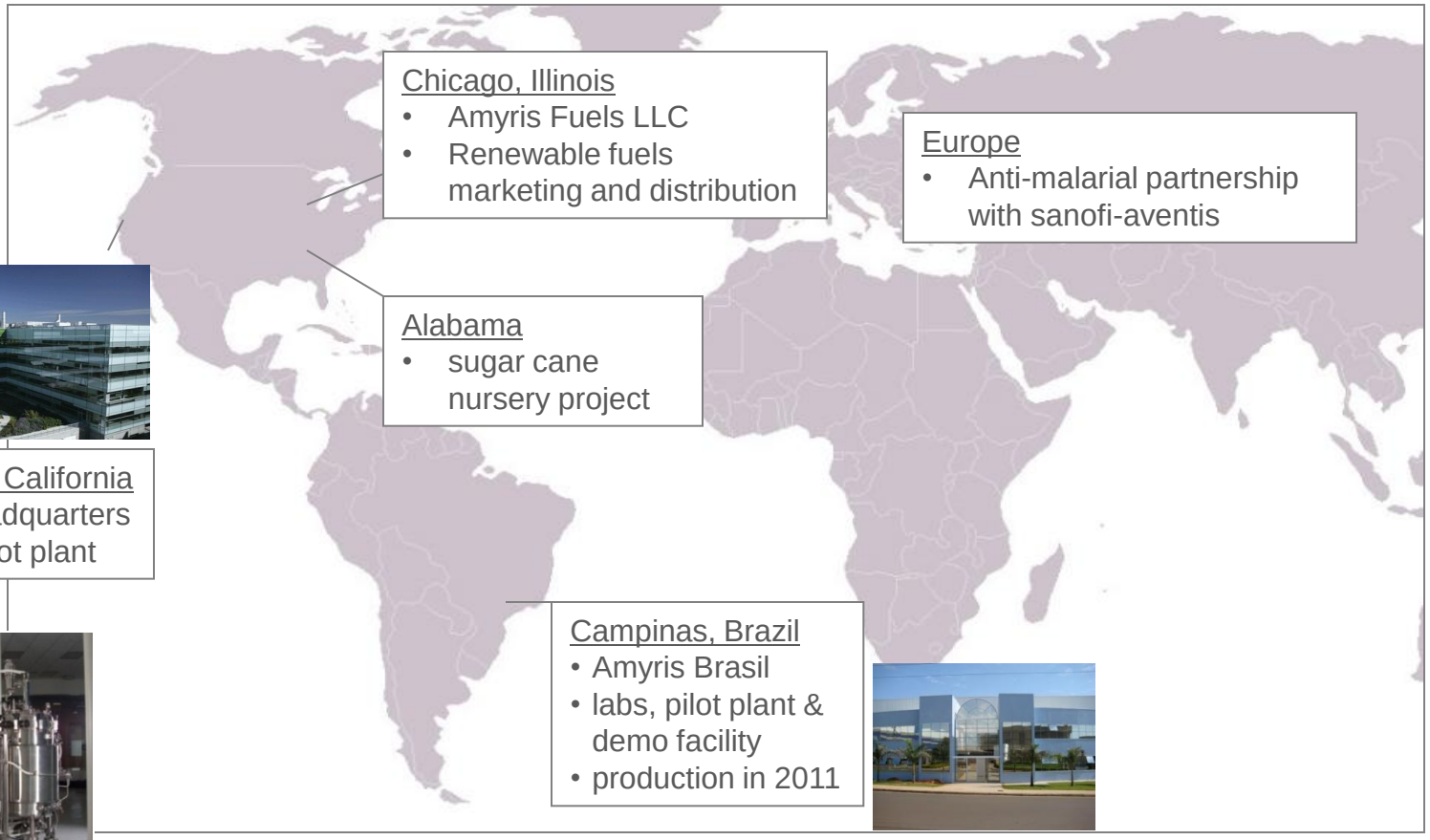
Company Overview

Amyris corporate office in Emeryville, CA

Amyris Crystalsev Biocombustíveis in Campinas, Brazil

- **Amyris is the leader in the race to produce and market advanced renewable fuels and chemicals**
  - **Proprietary technology that creates best-in-class fuels and chemicals ("programmed yeast")**
  - **Using industrial platform at sugar mills to ferment higher value added products**
  - **Comprehensive business model (i.e. GreenLane™) that enables us to take fuel from the plant to the market**

Amyris today



Chicago, Illinois
- Amyris Fuels LLC
- Renewable fuels marketing and distribution

Europe
- Anti-malarial partnership with sanofi-aventis

Alabama
- sugar cane nursery project

Emeryville, California
- ABI headquarters
- labs, pilot plant

Campinas, Brazil
- Amyris Brasil
- labs, pilot plant & demo facility
- production in 2011

… combining great science and innovative business to create a more sustainable world

Sugar + biotechnology + yeast = wide range of products

Traditional oil source

Oil

\+

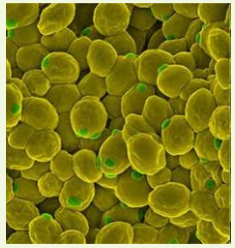
Refinery

= **Petroleum products**

Amyris renewable pathway

Sugar cane

\+



Amyris genetically engineered yeast

\+

Cane mill

= **> 50,000 isoprenoid compounds**

Bio-derived products

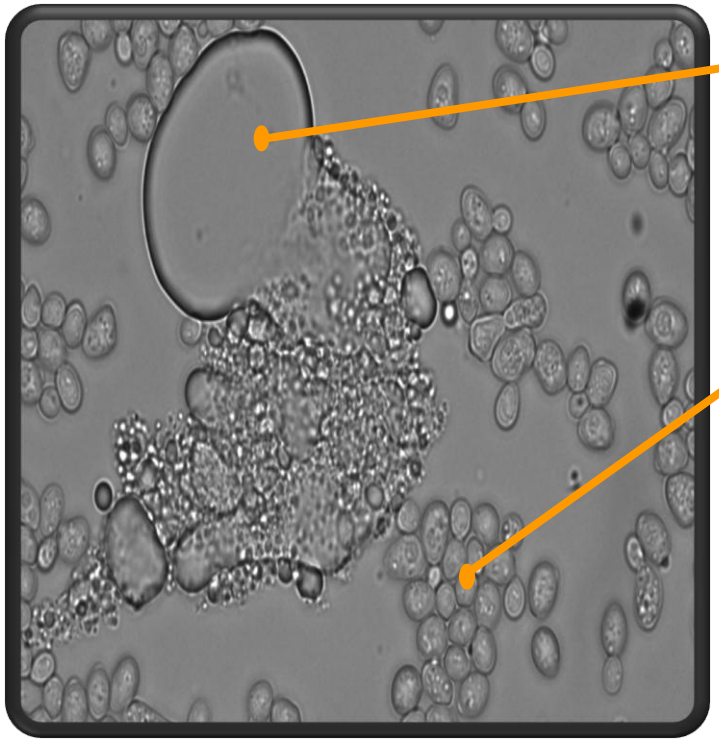
diesel
2020 estimate 450 billion gallons

jet fuel
2020 estimate 124 billion gallons

specialty chemicals: synthetic rubbers, lubricants, etc.

malaria drug
non-profit: treat over 200 million people annually

The power of biotechnology: traditional fermentation producing higher value diesel



Amyris diesel precursor

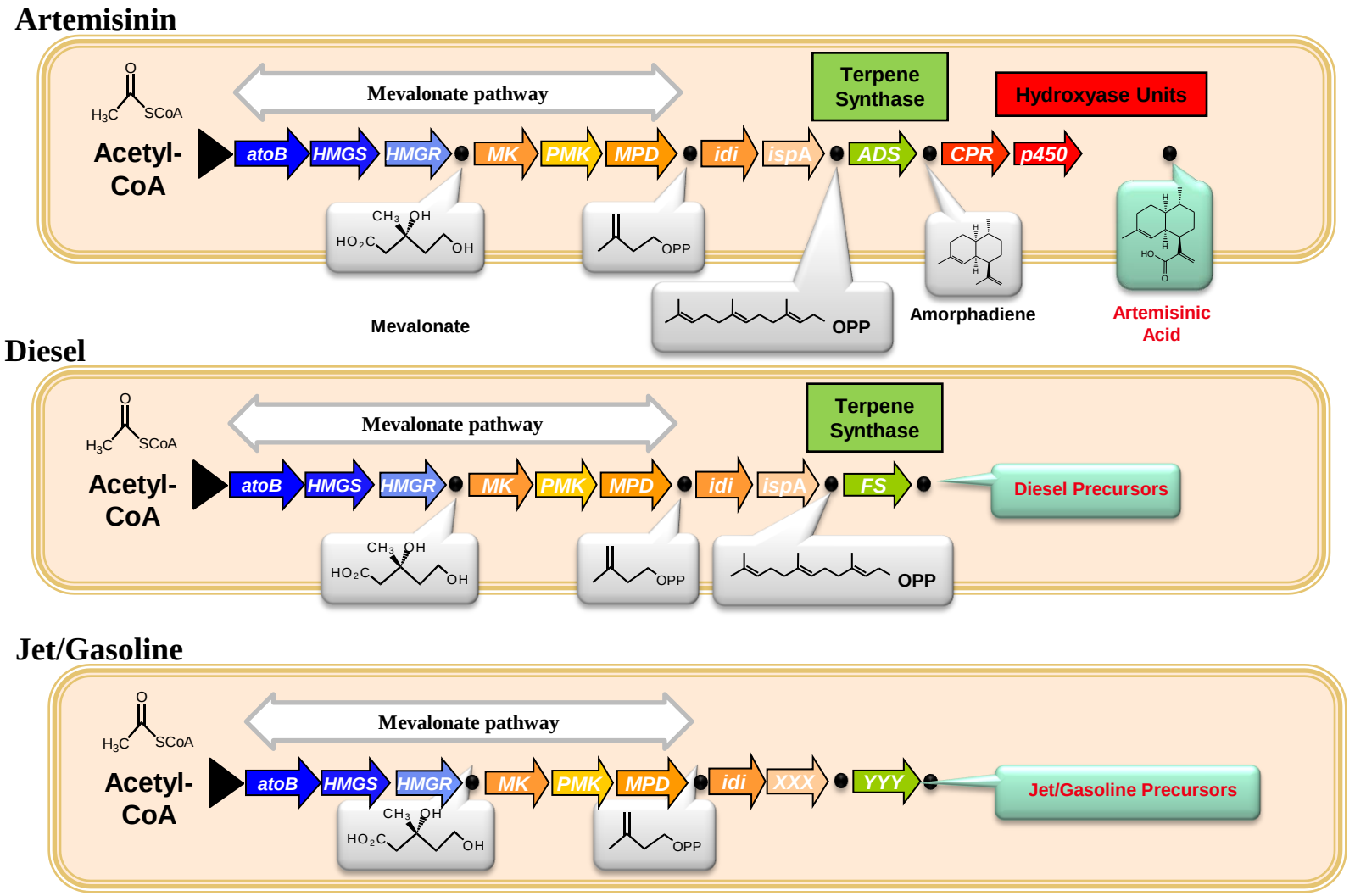
Amyris engineered yeast

Amyris diesel fuel

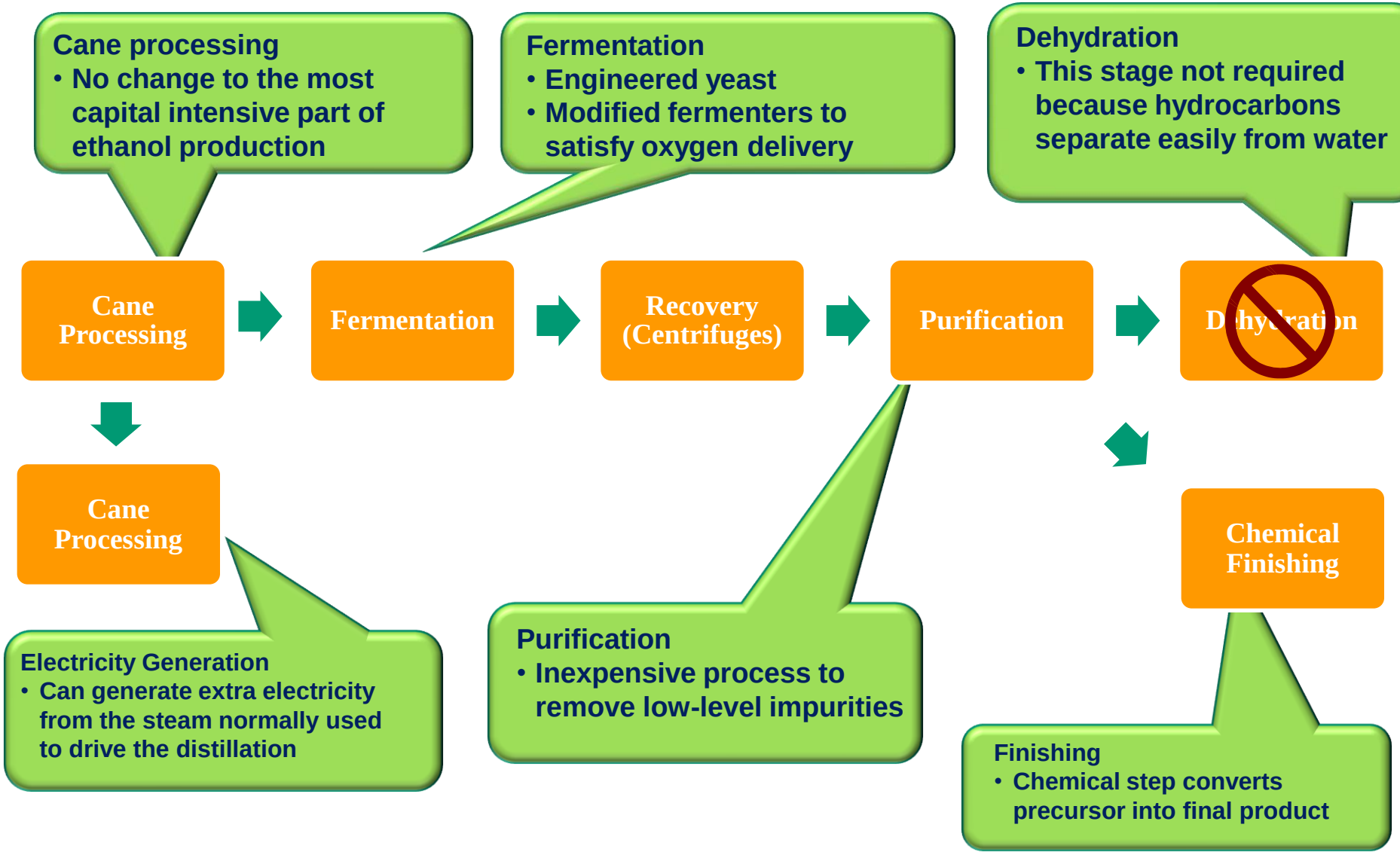
Petroleum diesel

Micrograph of fermentation fluids from production of Amyris Renewable Diesel (April, 2008)

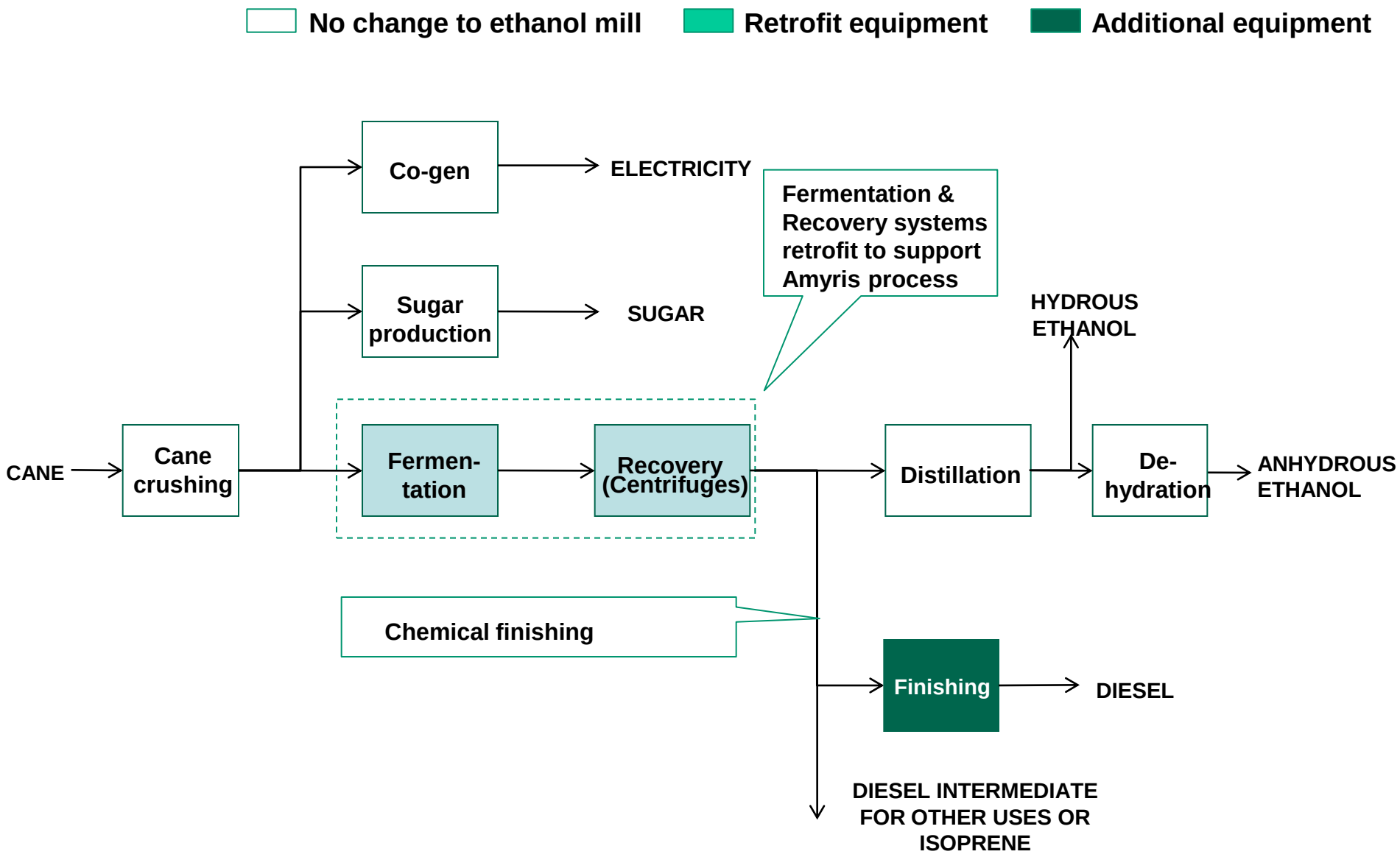
A platform technology for production of multiple products



Amyris's sugarcane to diesel production process



Converting na ethanol mill into a bio-refinery



Campinas pilot plant – Fermentation area

Campinas pilot plant – Downstream separation area

AMYRIS

Campinas Pilot Plant – media preparation area

- Thanks!

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