VI ENCONTRO DA ESCOLA BRASILEIRA DE QUÍMICA VERDE

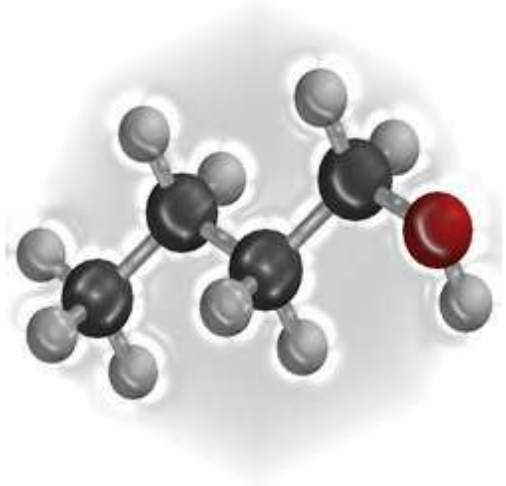
Biorrefinarias: A matéria-prima definindo o processo

26 e 27 - Set/2016

CTBE/CNPEM, Campinas-SP

Sessão Plenária: Integração de processos e produtos de uma biorrefinaria: O caso da cana de açúcar

Avaliação técnico-econômica do processo de produção de butanol integrado a uma biorrefinaria de primeira e segunda geração de cana-de-açúcar



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Biorefinery Concept

The biorefinery integrates biomass conversion processes and equipment to produce biofuels for mobility, power, and sugar feedstock from biomass. This concept is analogous to a petroleum refinery, which produces multiple fuels and products from petroleum

Biomass production system

- Sugar crops
- Starch crops
- Lignocellulosic biomass
- Residues

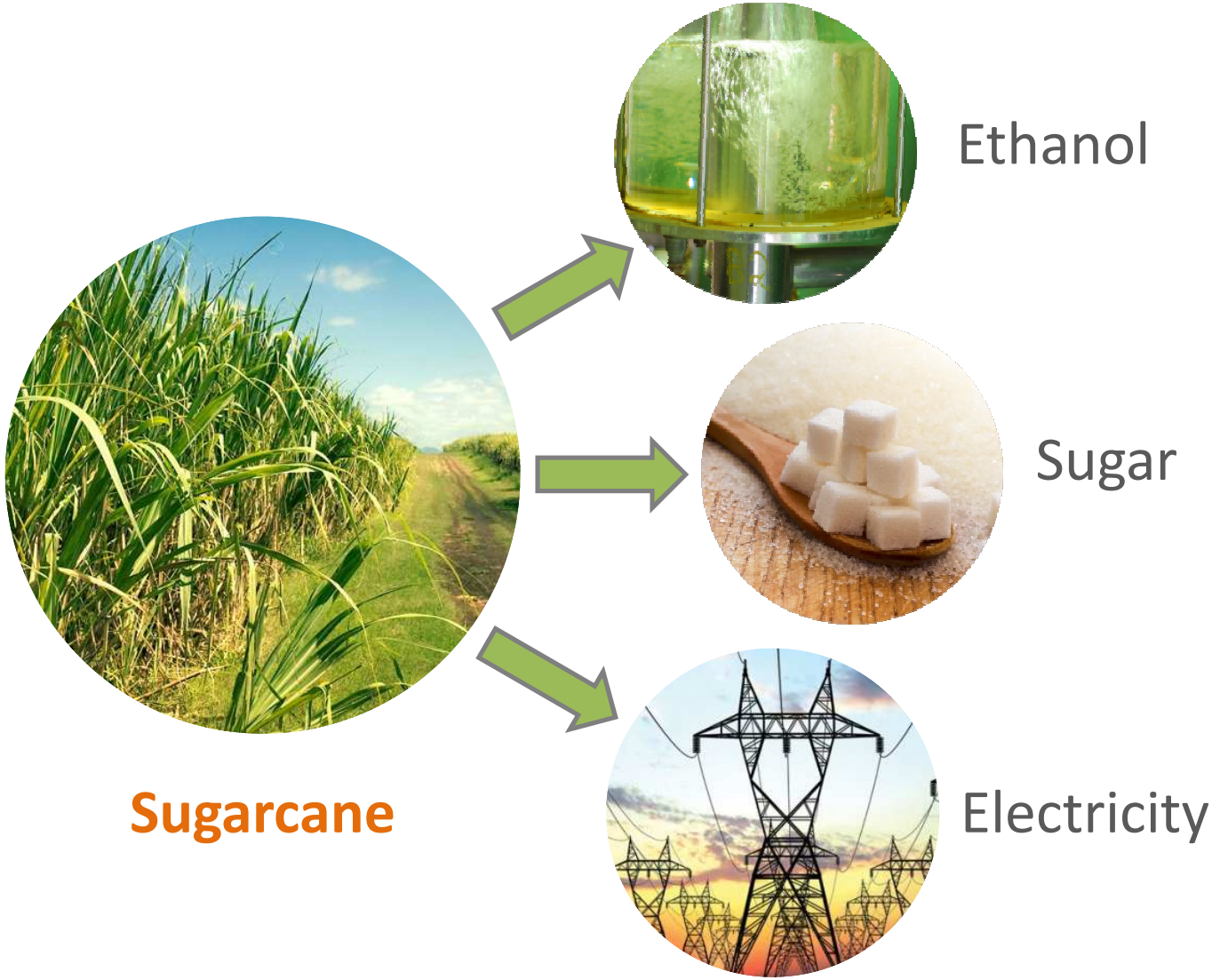
Processing technologies

- Bioprocesses
- Chemical processes
- Thermochemical processes
- Physical processes

Products (materials and energy), logistics and use

- Fuels
- Chemicals
- Materials
- Specialty chemicals
- Commodities

Sugarcane Biorefinery



Virtual Sugarcane Biorefinery

Model integration

Process simulation

Mathematical models

Sustainability impacts

- Assess different routes and technologies
- Assess stage of development of new technologies
- Optimize concepts and operations in the Biorefinery

Importance of n-Butanol

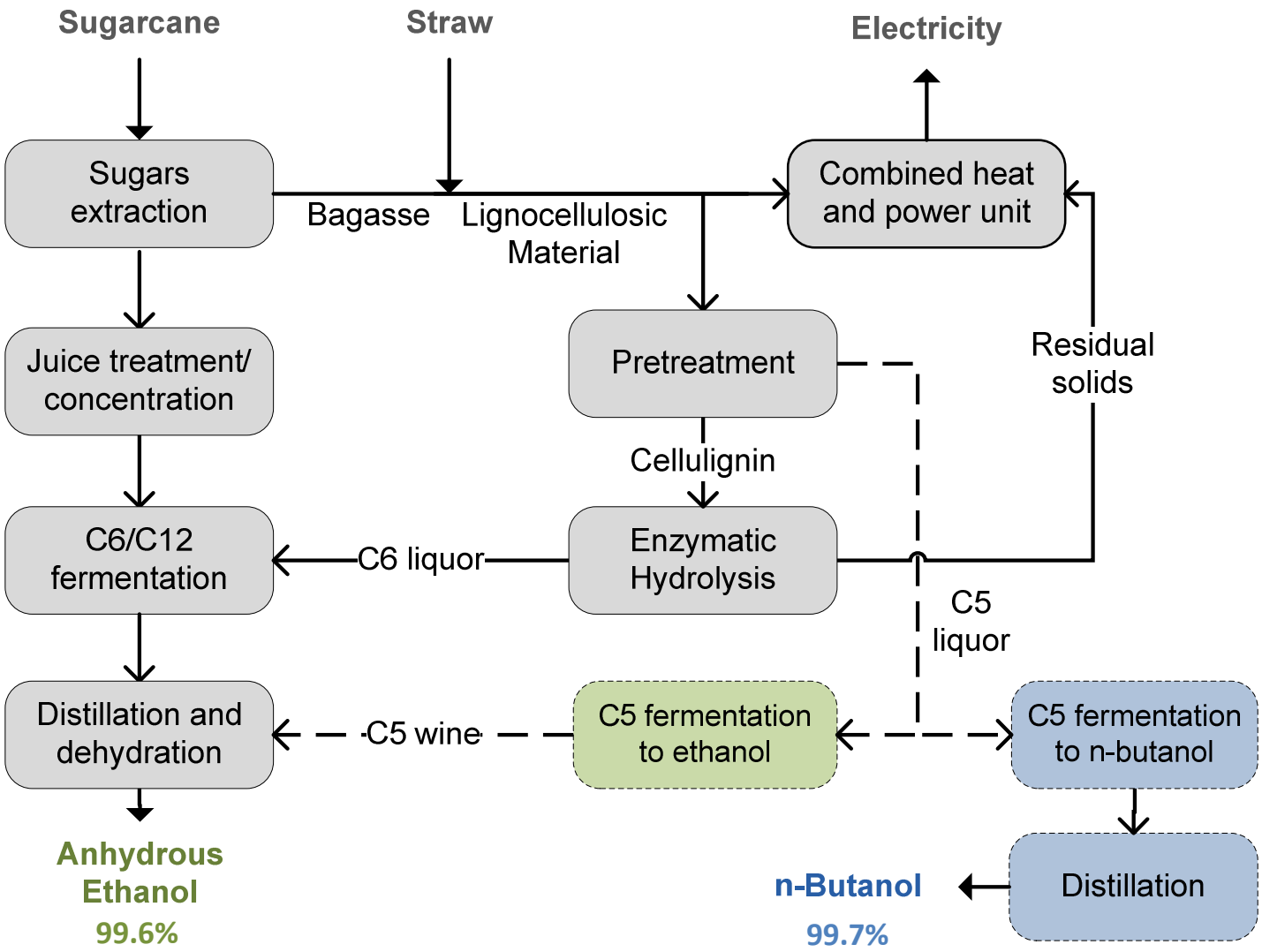
Use of renewable feedstock

Alternative utilization of pentoses liquor

Possibility of use as drop-in fuel

Attractive price as commodity chemical

Integrated 1G2G process



Evaluated scenarios

1G2G

- Ethanol production from juice, C6 and C5 liquor
- Electricity production on back-pressure turbines

1G2G-ButOH

Chemical

Fuel

- Ethanol production from juice and C6 liquor
- Butanol production from C5 liquor
- Electricity production on back-pressure turbines

1G configuration and parameters

- 1G: optimized autonomous distillery, producing ethanol and electricity
    - Optimization features: electrified drivers, molecular sieves for ethanol dehydration, reduced steam consumption, 65 bar boilers

Feedstock processing	
Sugarcane stalks (t/year)	4,000,000
Sugarcane straw (t/year), dry basis	180,000

This amount added to vegetal impurities represent 50% of produced straw

2G and butanol production

- **2G process:** configuration and parameters based on medium term technology (2021-2025) from Milanez et al. (BNDES Setorial 41, p. 237-294, 2015)
- **Butanol fermentation:** configuration and parameters assumed for an evolved strain (non-GMO) based on ongoing CTBE research, which focuses on:
  - Adaptation to medium with inhibitors
  - ↓ by-products
  - ↑tolerance to butanol
- **Butanol purification:** carried out in a series of 4 distillation columns and a decanter (liquid-liquid separation)

Operation

- 1G ethanol production
  - During sugarcane harvest season
  - 200 days
- 2G ethanol and butanol production
  - 330 days
  - Storage of lignocellulosic material for off-season operation
- Combined heat and power generation
  - 330 days
  - Provide steam and electricity to the process
  - Different requirements in each period (season and off-season)

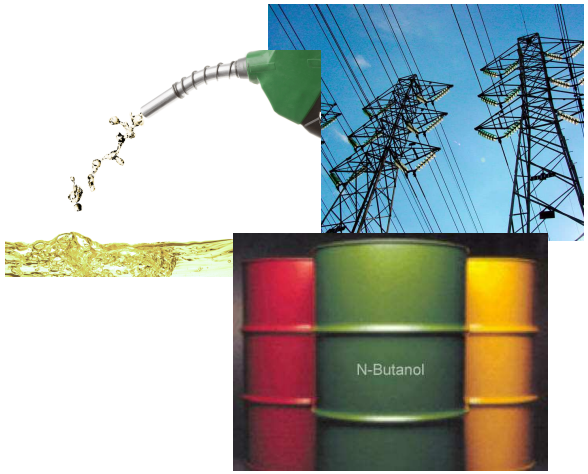
Main assumptions for economic assessment

- Análise *greenfield* dos projetos

Economic parameters	
Maintenance (% CAPEX)	**3%**
Tax rate (income and social contributions)	34%
Project lifetime (years)	**25**
Salvage value of the industrial plant	10%
Linear depreciation (% per year)	10%
Minimum acceptable rate of return	**12%**

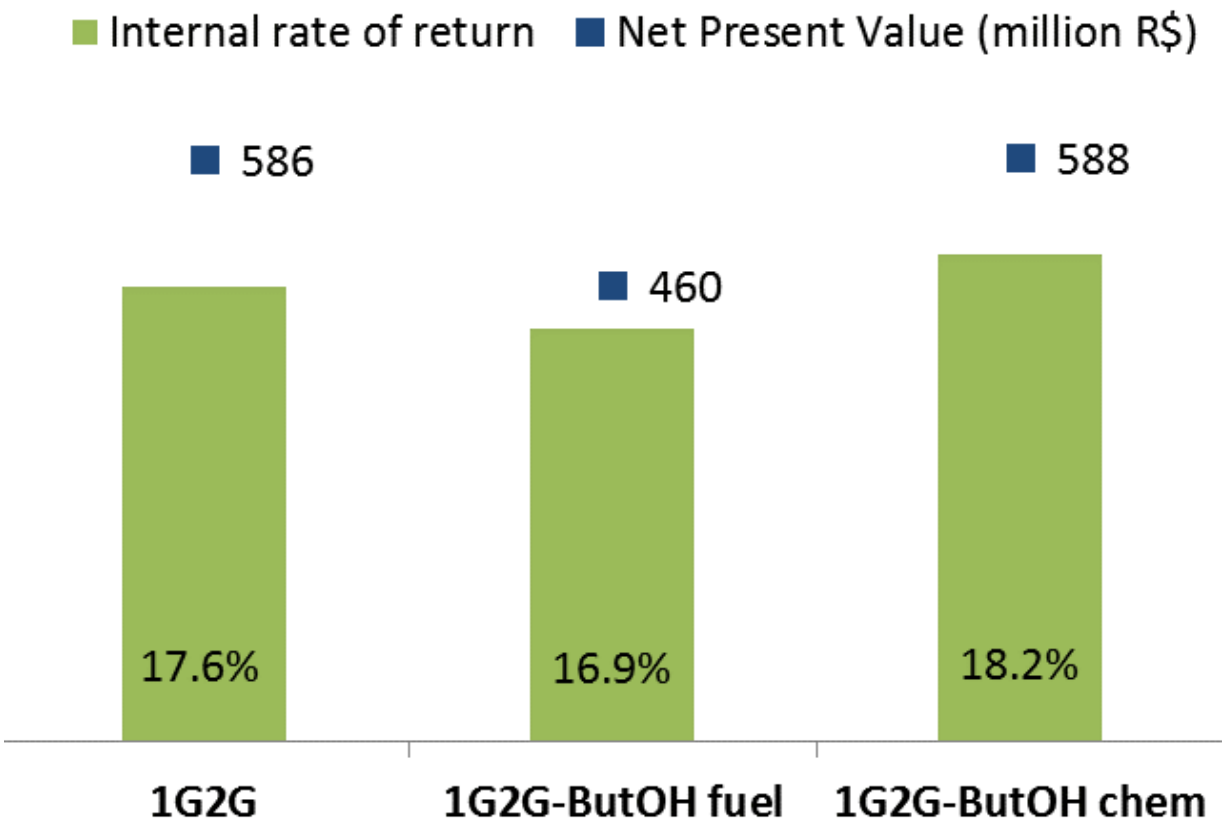
Feedstock costs	
Sugarcane stalks (R$/t)	69.09
Sugarcane straw (R$/t) – dry basis	77.71
Products prices	
n-Butanol – fuel (R$/kg)	**2.44**
n-Butanol – chemical (R$/kg)	**4.25**
Anhydrous ethanol (R$/L)	1.56
Electricity (R$/MWh)	182.47

Technical results



- 1G2G-ButOH (comparison to 1G2G scenario):
  - Higher steam consumption → lower availability of biomass for 2G process
  - Significant reduction on 2G ethanol output (↓ biomass, alternative destination of C5)
  - Annual production 17 kt of butanol - around 20% of yearly consumption in Brazil
  - Similar electricity output

Economic results



Final remarks

- Commercialization of by-products (e.g. butyric acid) may increase profitability of butanol production.
- The use of less energy-intensive processes (e.g. molecular sieves) for n-butanol purification may increase biomass availability.
- n-Butanol obtained from pentoses can replace fossil-derived chemicals, but it has to be cost-competitive considering oil price volatility.
- The use of n-butanol as gasoline substitute would have large market potential.

Thank you!

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