# **2nd Generation Cane Ethanol: The Potential**

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### 2<sup>nd</sup> Gen Cellulosic Ethanol

2nd

Generation

**Cane Ethanol** 

What could be achieved at

pilot scale in 3 years given a

substantial technology

*development effort?* 

# **A Role of Biomass in America's Energy Future Project**

 Most comprehensive study of <u>mature</u> cellulosic energy technology

- 8 articles in *BioFPR* special issue
- Did not consider sugar cane

#### Updated based on experience of Mascoma Corp

• 200 person-year technology development effort since 2006

#### **Key technology features**

- Advanced pretreatment
  - Consolidated bioprocessing (no added cellulase)
    - Pentose conversion
      - Thermal integration

1<sup>st</sup> Gen Cane Ethanol

Model developed over last year drawing from

Bohlman & Cesar, 2006 (SRI)

**Oliverio and Ferreira, 2010** 

Input from Brazilian colleagues

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- Luís Cortez<sup>6,11</sup>
- Rubens Maciel Filho<sup>11</sup>
- Eduardo Almeida<sup>7,11</sup>
- Silvia Azucena Nebra<sup>10,11</sup>
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- Manoel Regis Lima Verde Leal<sup>1,3,10,11</sup>
- Luis Rodrigues<sup>2</sup>
- Maria Aparecida Silva<sup>9,11</sup>
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Further collaborative validation planned

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#### **Scenarios examined**

- 1) Gen 1 ethanol with cogen (bagasse only)
- 2) Gen 1 ethanol with cogen (+ trash)
- 3) Gen 1 + Gen 2 ethanol with cogen (bagasse only)
- 4) Gen 1 + Gen 2 ethanol with cogen (+ trash)
- 5) Scenario 4 + increased thermal integration



## **Ethanol and Electricity Yields**

• Ethanol yield per ton, and per hectare, doubled for 2<sup>nd</sup> gen with thermal integration (scenario 5 vs scenario 1)

• Electricity export is substantial for 2<sup>nd</sup> gen scenarios 3 and 4, but not scenario 5 which just generates electricity used

#### Parameters

- 0.15 kg dry bagasse /kg wet cane (70% moisture)
- 0.1 kg dry harvested trash/kg wet cane

•Gen 2 ethanol yield: 78% of theoretical

# **Operating and Capital Cost**



### ОрЕх

Lower with 2<sup>nd</sup> gen ethanol because more value is derived from the feedstock

 $\rightarrow$  Robustness to price volatility

### CapEx

Lower per liter for combined 1<sup>st</sup> & 2<sup>nd</sup> gen ethanol (scenarios 3, 4, and 5) compared to 1<sup>st</sup> gen ethanol + electricity (scenarios 1 and 2) because cogen capital per liter is less

- 1) Gen 1 with cogen (bagasse only)
- 2) Gen 1 with cogen (+ trash)
- 3) Gen 1 + Gen 2 with cogen (bagasse only)
- 4) Gen 1 + Gen 2 with cogen (+ trash)
- 5) Scenario 4 + increased thermal integration

#### Parameters

- •6 million Mg cane/year
- •39 R/Mg cane (70% moisture)
- •55 R/Mg trash (15% moisture)
- •0.93 R/L ethanol
- •120 R/MWh
- •15% IRR
- •100% equity financing, 20-year SL depreciation
- •39% income tax rate
- •1.57 R/US\$

## **Minimum Ethanol Selling Price (MESP)**



1) Gen 1 ethanol + electricity

- 2) Gen 1 ethanol + electricity (+ trash)
- 3) Gen 1 + 2 ethanol + electricity (bagasse only)
- 4) Gen 1 + 2 ethanol + electricity (+ trash)

5) Scenario 4 w/increased thermal integration

Cane must be processed immediately whereas bagasse & trash can be stored

Thus year-round operation is possible with 2<sup>nd</sup> gen feedstocks

→ More efficient use of capital, lower minimum ethanol selling price

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### **Process Energy Flows** Scenario 4, Normalized to Cane Heating Value



# Potential Impact of 2<sup>nd</sup> Generation Cane Ethanol in Brazil

Saudi Arabia (EtOH equivalent)<sup>b</sup>

Global gasoline (EtOH equivalent)

 $2^{nd}$  gen EtOH conversion allows energy cane to be used in lieu of sugar cane  $\rightarrow 2x$  tons per acre

 $2^{nd}$  gen EtOH conversion  $\rightarrow 2x$  yield of ethanol per ton compared to  $1^{st}$  gen only

60 Mha available land presently occupied with degraded pasture that can be used to grow sugar cane with no significant impact on environment and biodiversity<sup>a</sup> **15**x

1<sup>st</sup> gen EtOH, current Brazil production, from 4 Mha



<sup>a</sup>Comprehensive eco-agricultural study for the Brazilian Ministry of Agriculture, mentioned in Lynd et al., 2011. <sup>b</sup>12.5 million barrels/day, 72 L gasoline/barrel, 1.5 L ethanol equivalent/L gasoline