2nd Generation Cane Ethanol: The Potential

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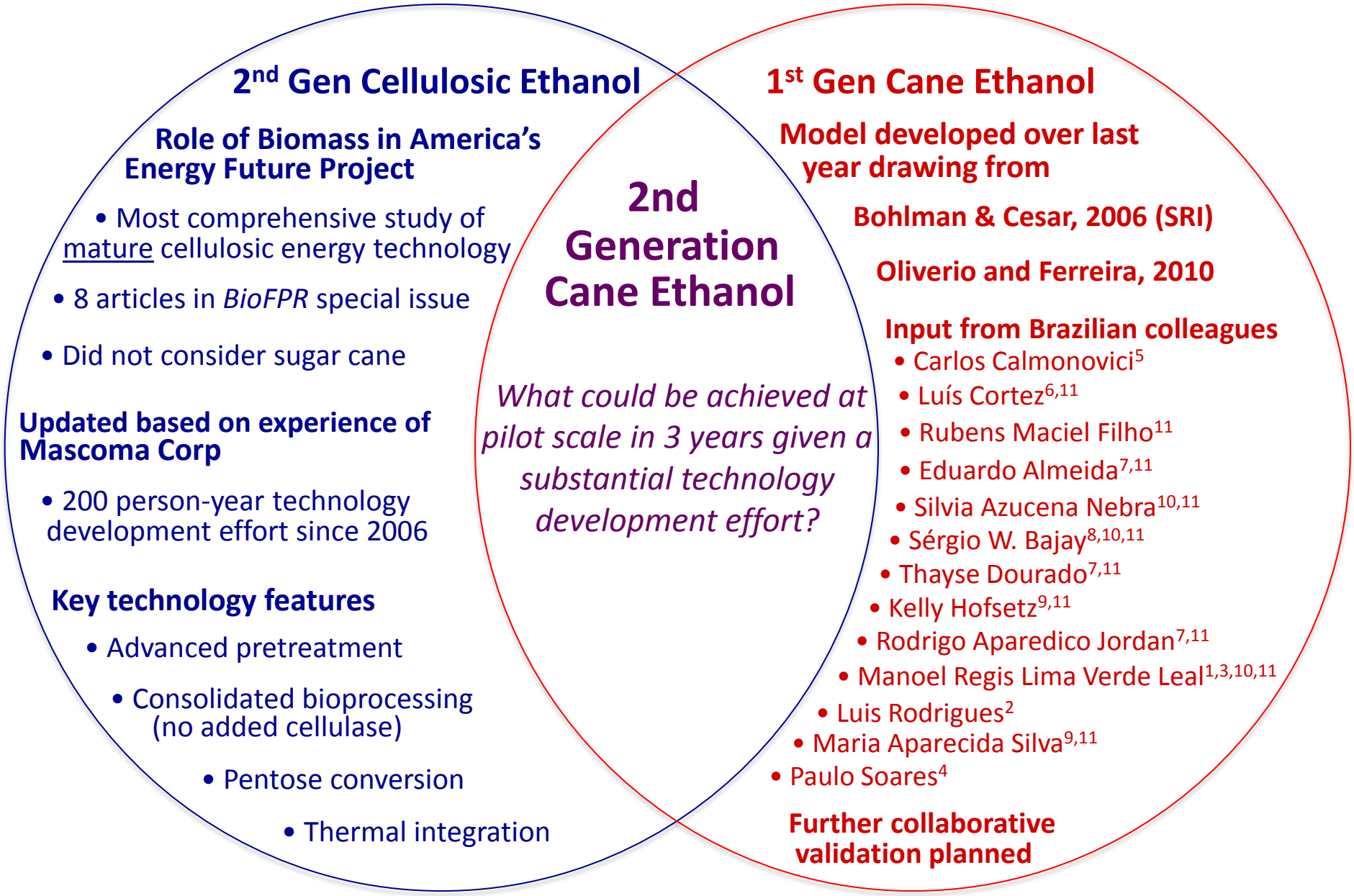
MASCOMA

1867 THAYER SCHOOL OF ENGINEERING AT DARTMOUTH



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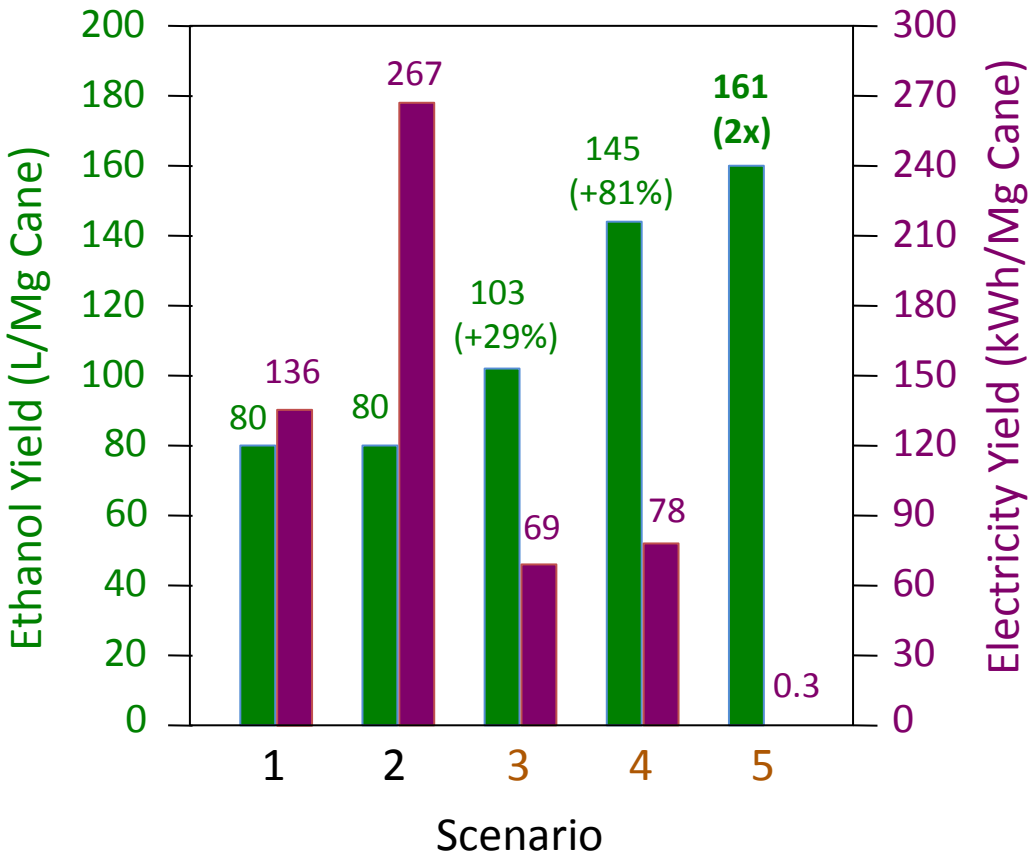
Scenarios examined

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

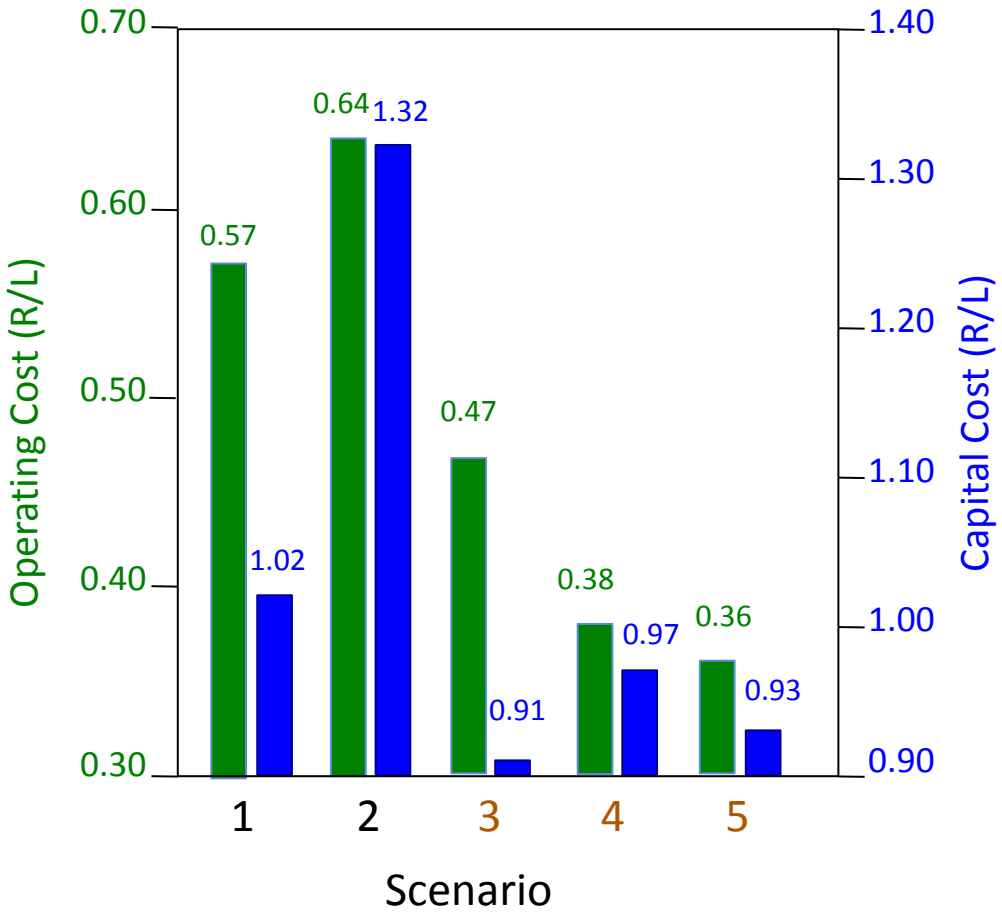


- Ethanol yield per ton, and per hectare, doubled for 2nd gen with thermal integration (scenario 5 vs scenario 1)
- Electricity export is substantial for 2nd gen scenarios 3 and 4, but not scenario 5 which just generates electricity used

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



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

OpEx

Lower with 2nd gen ethanol because more value is derived from the feedstock

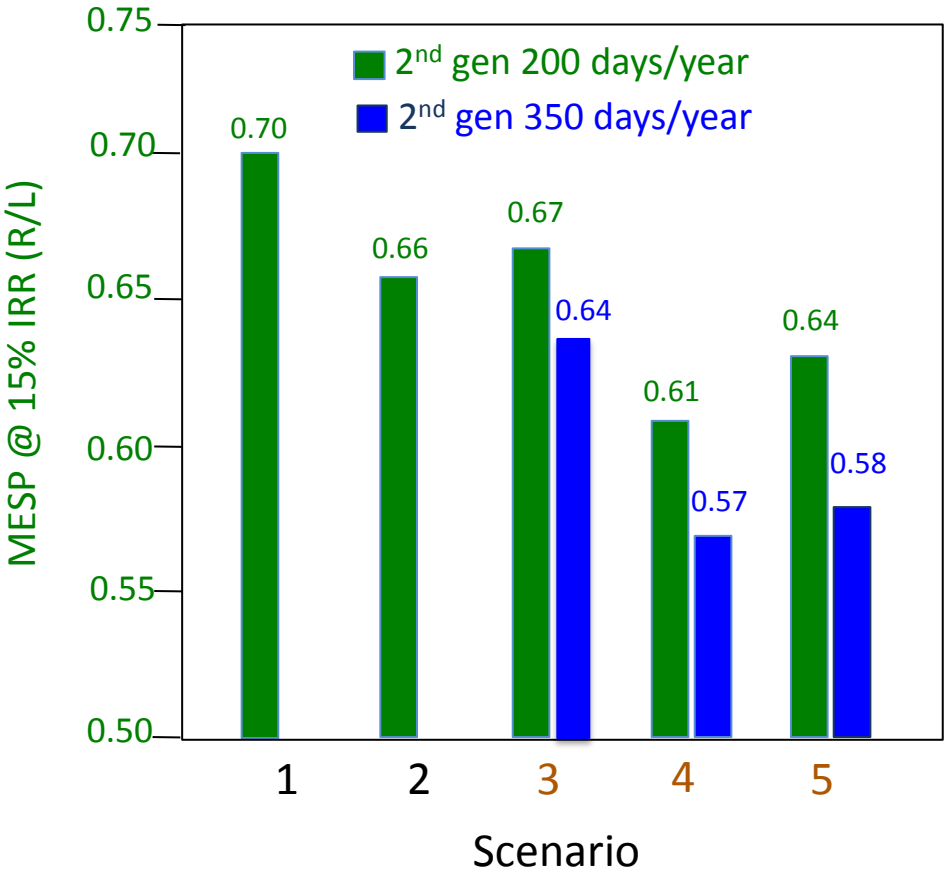
→ Robustness to price volatility

CapEx

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

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)



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

Thus year-round operation is possible with 2nd gen feedstocks

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

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

Parameters
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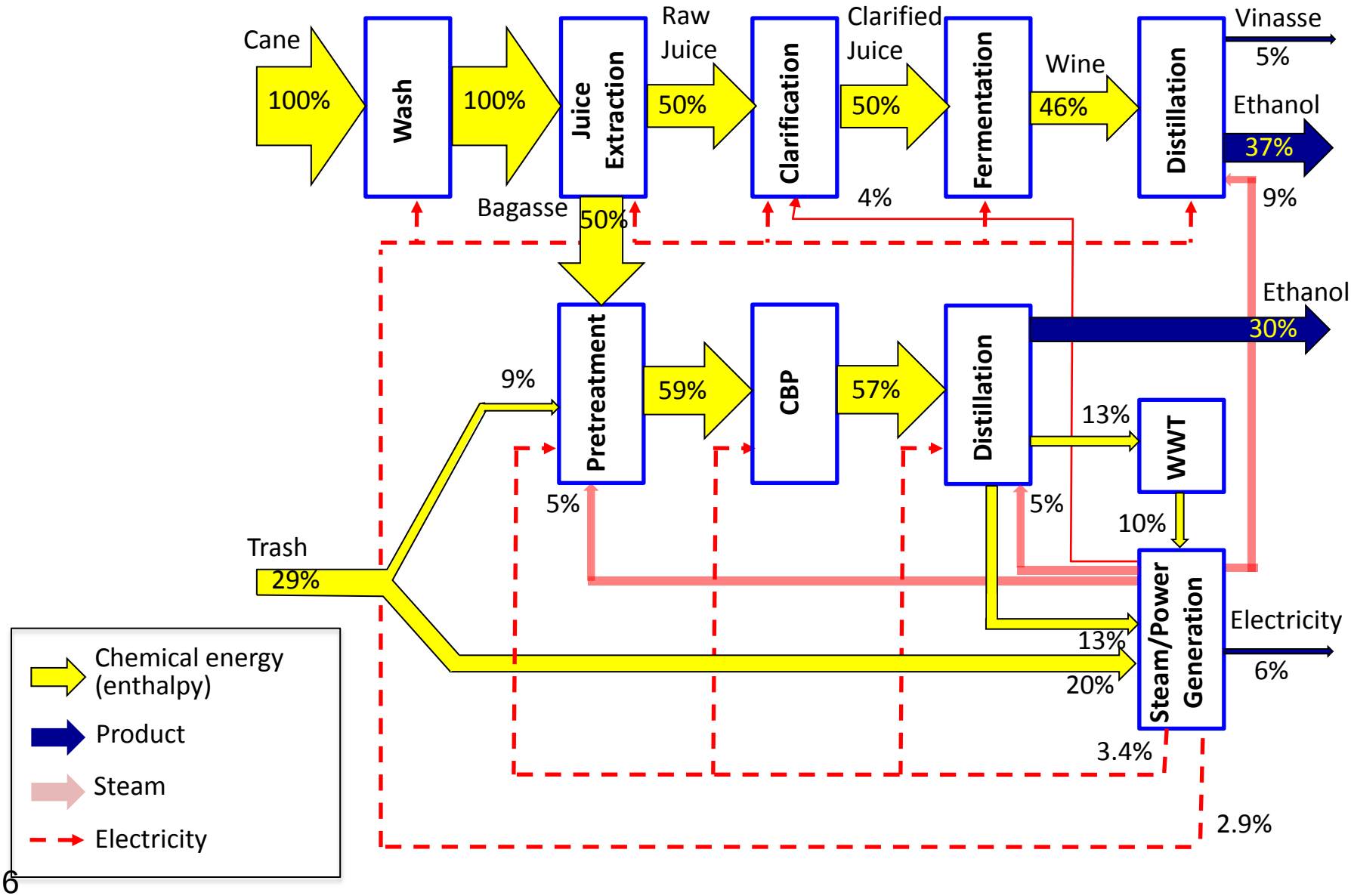
Process Energy Flows

Scenario 4, Normalized to Cane Heating Value



Potential Impact of 2nd Generation Cane Ethanol in Brazil

Saudi Arabia (EtOH equivalent)[b]

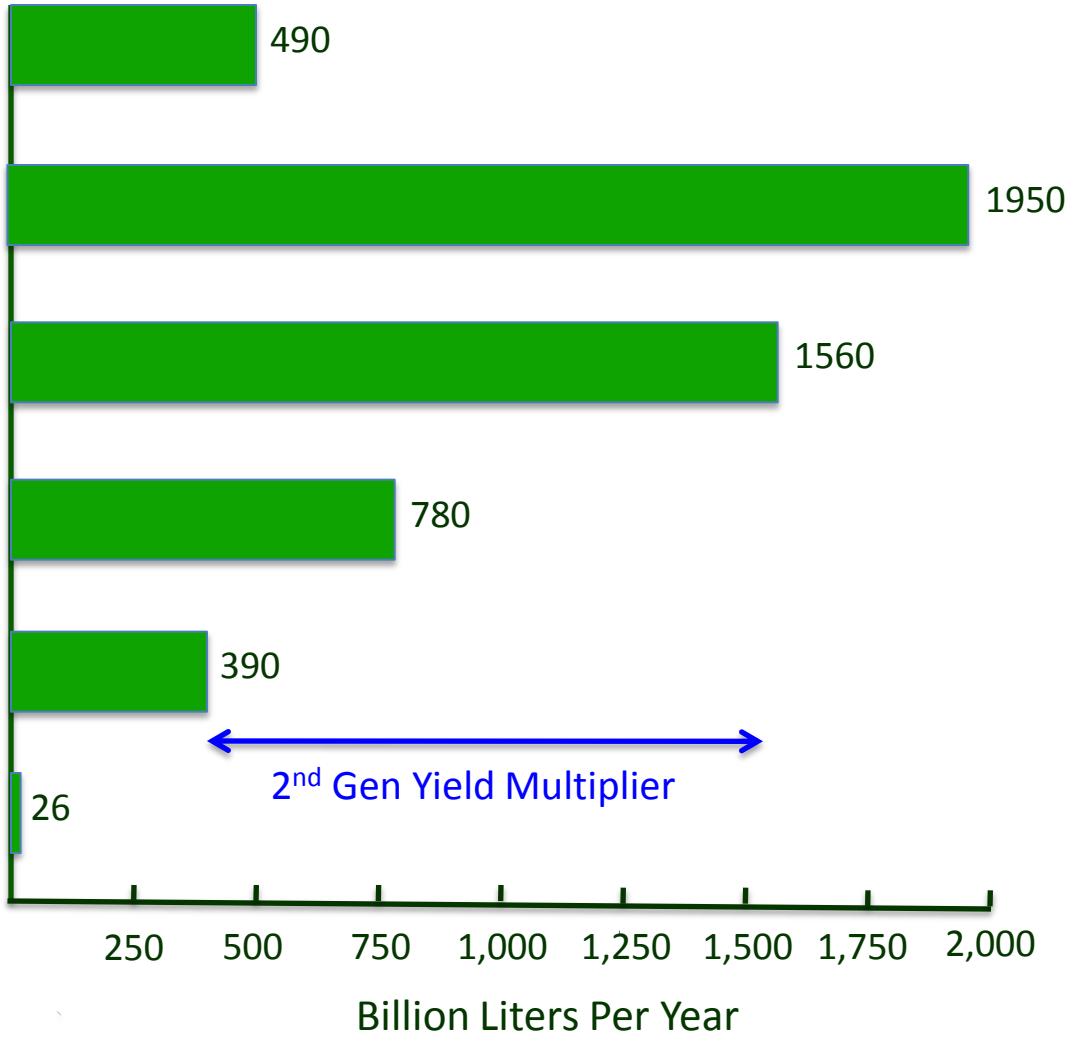
Global gasoline (EtOH equivalent)

2nd gen EtOH conversion allows energy cane to be used in lieu of sugar cane → **2x** tons per acre

2nd gen EtOH conversion → **2x** yield of ethanol per ton compared to 1st 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[a] **15x**

1st gen EtOH, current Brazil production, from 4 Mha



[a]Comprehensive eco-agricultural study for the Brazilian Ministry of Agriculture, mentioned in Lynd et al., 2011.

[b]12.5 million barrels/day, 72 L gasoline/barrel, 1.5 L ethanol equivalent/L gasoline