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Optimization of bagasse utilization for ethanol production

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Introduction & Motivation

Sugarcane → Mills → Bagasse

Availability of sugar processing waste

- Sugarcane processing gives bagasse as waste
- 1 Mg cane ➡ 280 kg bagasse.
- Bagasse presently used as boiler feed and fodder.
- More profitable uses of bagasse need to be explored

Production of second generation biofuels

- Renewable liquid transportation fuels becoming important.
- Second generation biofuels from non-food crops attractive.
- Should be cost competitive with conventional fuels
- Co-production a possibility

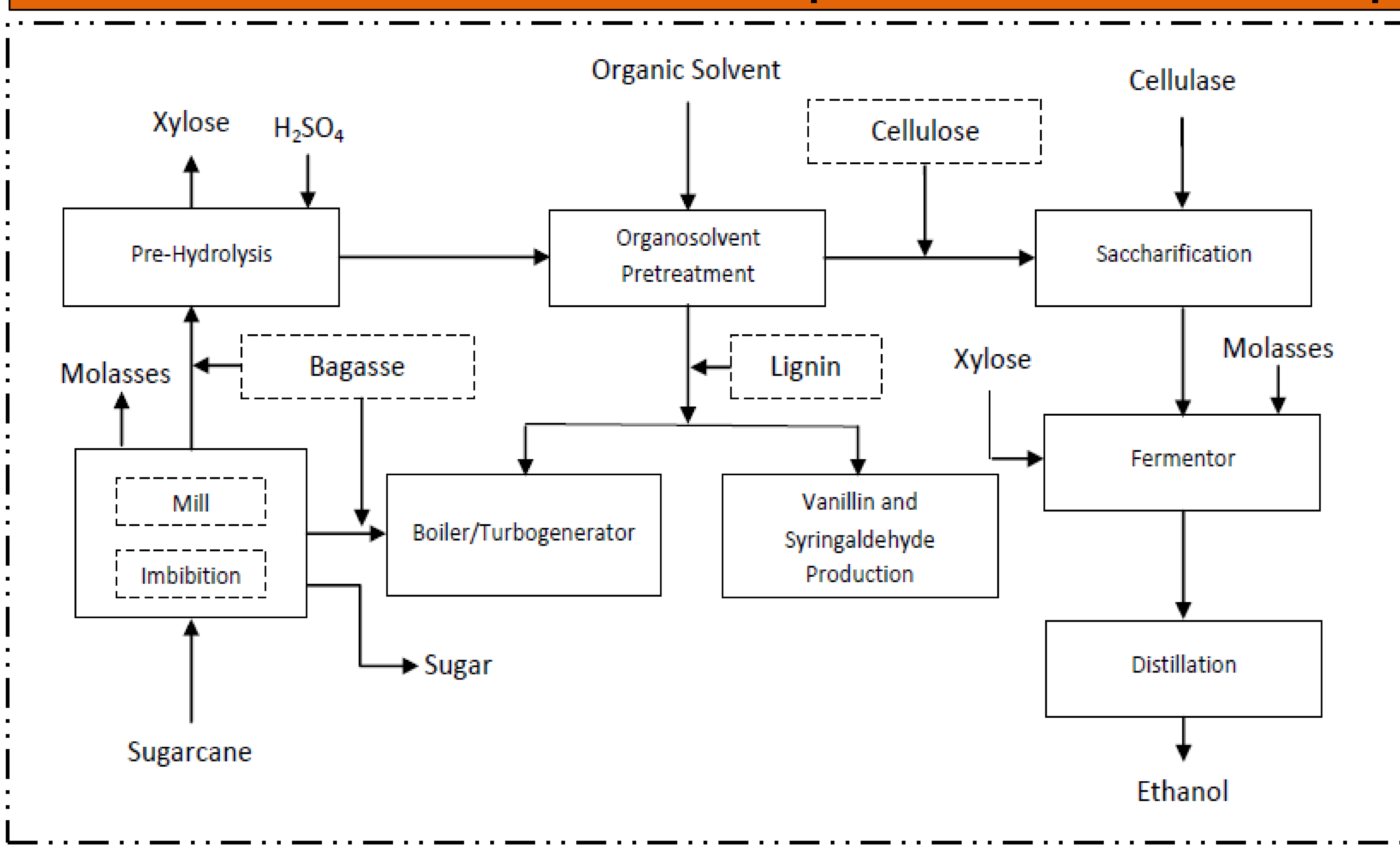
Objective

- Integrate bagasse to ethanol production in existing sugar mills
- Optimize the process synthesis for cost reduction
- Determine break even selling price (BESP) of ethanol
- Quantify impact of different factors on economic feasibility

Approach

- System level optimization model.
- Mass and Energy balances of processing units.
- Economics and equipment costing relationships.
- Maximization of overall profits.
- Inclusion of India specific data for India specific scenario.

Process Superstructure and Optimization Model Formulation



Objective $\quad Max\ z = \sum_i S.P_i \times x_i -$ Total Cost

where,

$S.P_i =$ Selling price of product i

$x_i =$ Quantity of product i

Subjected to :

$$x^{Bagasse}_{Boiler} + x^{Bagasse}_{Ethanol} = F^{Bagasse}$$

$$C.P_{Bagasse} + C.P_{Lignin} + C.P_{Trash} \geq Q_1 + x^{Bagasse}_{Ethanol} \times Q_2$$

$$x^{H_2SO_4}_{Cost} = f_{Annual} \times F_{H_2SO_4} \times C_{H_2SO_4} \times x^{H_2SO_4}_{B2}$$

Model statistics:

No. of constraints: 110
No. of variables: 112
No. of discrete variables: 2

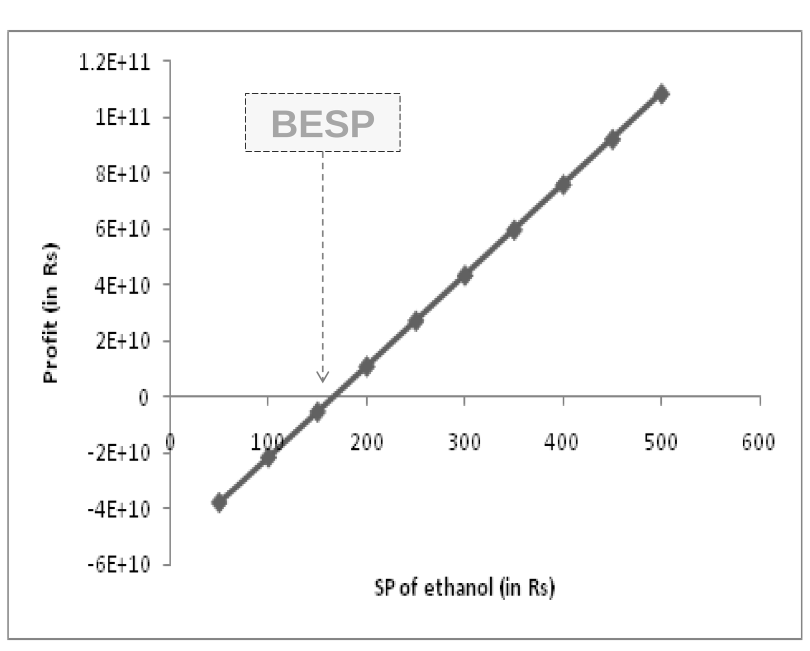
Key decision variables: $x^{Bagasse}_{Boiler}$ and $x^{Bagasse}_{Ethanol}$

BESP = Selling price of ethanol when z = 0

Case Study Application and Results

Case study and base case results

- 500 Mg/hr sugarcane feedstock
- Vanillin and syringaldehyde production are excluded

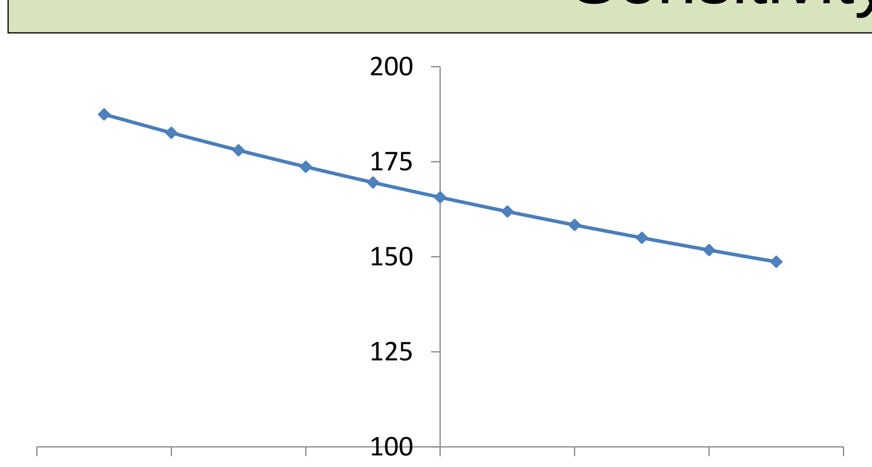


- Ethanol BESP was 165.65 Rs/litre.
- Allocation of 68.4 % bagasse for ethanol generation.
- All trash is utilized as energy source

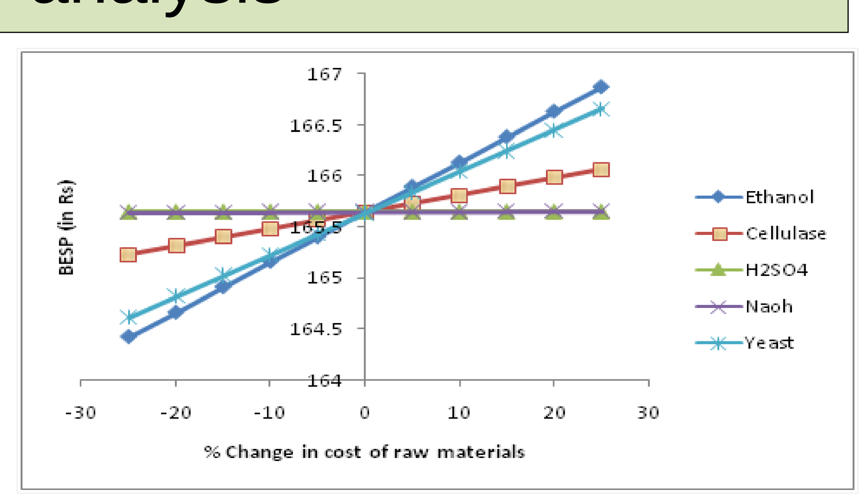
Scenario evaluation & comparison

Variable	Base Case (With Trash)	Scenario 1 (Without Trash)	Scenario 2 (Not sending lignin to boiler)
Bagasse to pre-treatment	41.89	14.88	34.91
Bagasse to boiler	19.33	46.35	26.32
Lignin to boiler	11.34	4.03	0
Lignin to vanillin	0	0	0
Trash utilized	34.84	0	34.84
Ethanol produced	32.43	16.12	28.21
BESP (Rs/litre)	165.65	319.16	188.34

Sensitivity analysis



2.36% increase in BESP for 5% decrease in trash recovery efficiency



BESP sensitivity order
Ethanol>Yeast>Cellulase>NaOH>H_2SO_4

Conclusions

- Better process integration and resource utilization required.
- Lack of trash utilization causes 64.4 % decrease in bagasse to ethanol production.
- Non-utilization of lignin for heat generation causes 16.6% decrease in bagasse to ethanol production.
- Integration of lignin and trash is essential for ethanol feasibility.
- Sensitivity results indicate more efficient organosolvent recovery required

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