

# Biorefinery Optimization Tool — Development and Validation

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## 1. Initial Premise

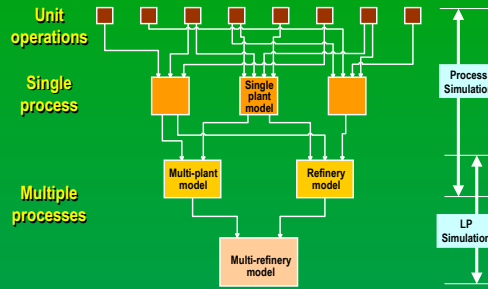
- Biorefinery concept proposed as means of improving economics of next-generation technologies
- Use various biomass feedstock options
- Produce a mix of fuels, power, and high-value co-products
- Must optimize feedstock and product mix
- Biorefinery similar to petroleum refinery

### Objective

Develop Excel-based software to optimize selection of feedstocks, products, and process configurations for conceptual biorefineries

- Use VBA Macros and Solver Add-In

## 2. Modeling Hierarchy



## 3. Comparison of Approaches

Process Simulation	LP and NLP Simulation
Model driven	Data driven
Relies on theories	Relies on mathematics
Engineering	Economics
Iterative solution	Equation oriented
Case studies	True optimization

## 4. LP Formulation

$$ax_1 - bx_2 + cx_3 + dx_5 = A$$

$$-ex_1 - fx_2 + gx_4 - hx_5 \leq B$$

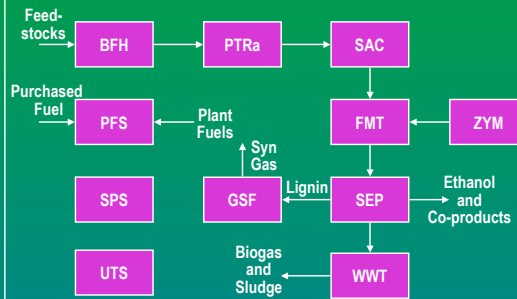
$$ix_1 - jx_3 + kx_4 \geq C$$

### LP Tableau

$x_1$	$x_2$	$x_3$	$x_4$	$x_5$	$s_1$	$s_2$	RHS
+a	-b	+c		+d			A
-e	-f		+g	-h	+1		B
+i		-j	+k			-1	C
+m	+n		-o	-p			Obj.

$s_1$  and  $s_2$  are slack variables *RHS*, Right Hand Side *Obj.*, Value of objective function

## 5. Biorefinery Block Flow Diagram

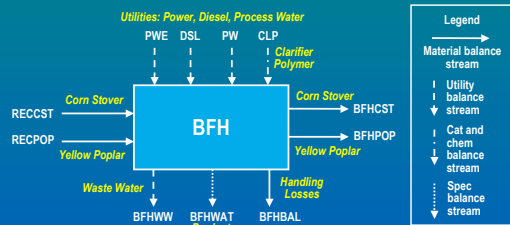


## 6. Worksheets in BioRefine.xls

<b>SOLV</b> Setup and solver	<b>SSEP</b> Co-product separations
<b>ECON</b> Economics	<b>SGSF</b> Gasification
<b>PURC</b> Purchases	<b>SZYM</b> Enzyme production
<b>SALE</b> Product sales	<b>SWWT</b> Waste water treatment
<b>SBFH</b> Biomass feed handling	<b>SPFS</b> Plant fuel system
<b>SPTR</b> Pretreatment	<b>SUTS</b> Other utility systems
<b>SSAC</b> Saccharification	<b>SSPS</b> Steam and power
<b>SFMT</b> Fermentation	

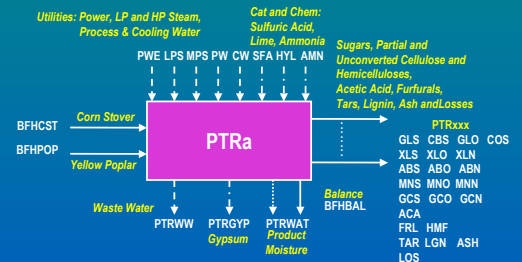
## 7. SBFH — Biomass Feed Handling

Receiving, storage, washing and sizing of biomass feedstocks



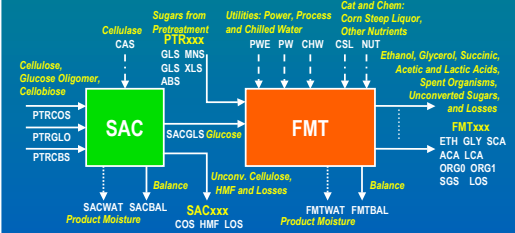
## 8. SPTRa — Biomass Feed Pretreatment

Mild/severe acid hydrolysis pretreatment of washed and sized biomass feedstocks



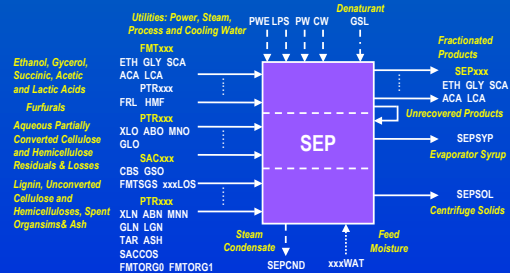
## 9. SSAC — Cellulose Saccharification SFMT — Sugar Fermentation

Simultaneous enzymatic saccharification and microbial fermentations to ethanol and lactic acid

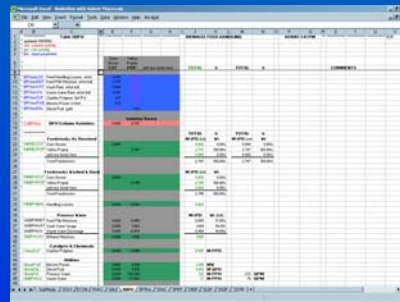


## 10. SEEP — Co-Product Separation

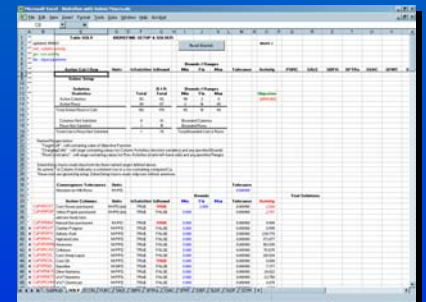
Recovery and purification of various products from hydrolysis and fermentation



## 11. SubModel Template



## 12. SubModel Template



## 13. Potential BioRefine.xls Studies

- Feedstocks
  - Corn Stover
  - Poplar
- Co-Products
  - Ethanol
  - Glycerol
  - Succinic Acid
  - Acetic Acid
  - Lactic Acid
  - Furfural
  - HMF
- Power Generation
  - CFBC with ST
  - GT and ST CC
- Other Products
  - Power
  - Waste Heat (steam)
  - Boiler Fuel
- Mild and Severe Hydrolysis
- Sugar Fermentation
  - Ethanol
  - Lactic Acid

## 14. Project Status

- Spreadsheet developed to optimize selection of feedstocks, products, and process configurations for conceptual biorefineries
  - Prototype delivered
- Further software development
  - User interface to improve ease of use
  - Automatic Solver setup
- Further verification of assumptions, structure, and data
- Biorefinery scenarios

## 15. Acknowledgement



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