

# Logistical Support and Modeling Efforts in Pretreatment Research

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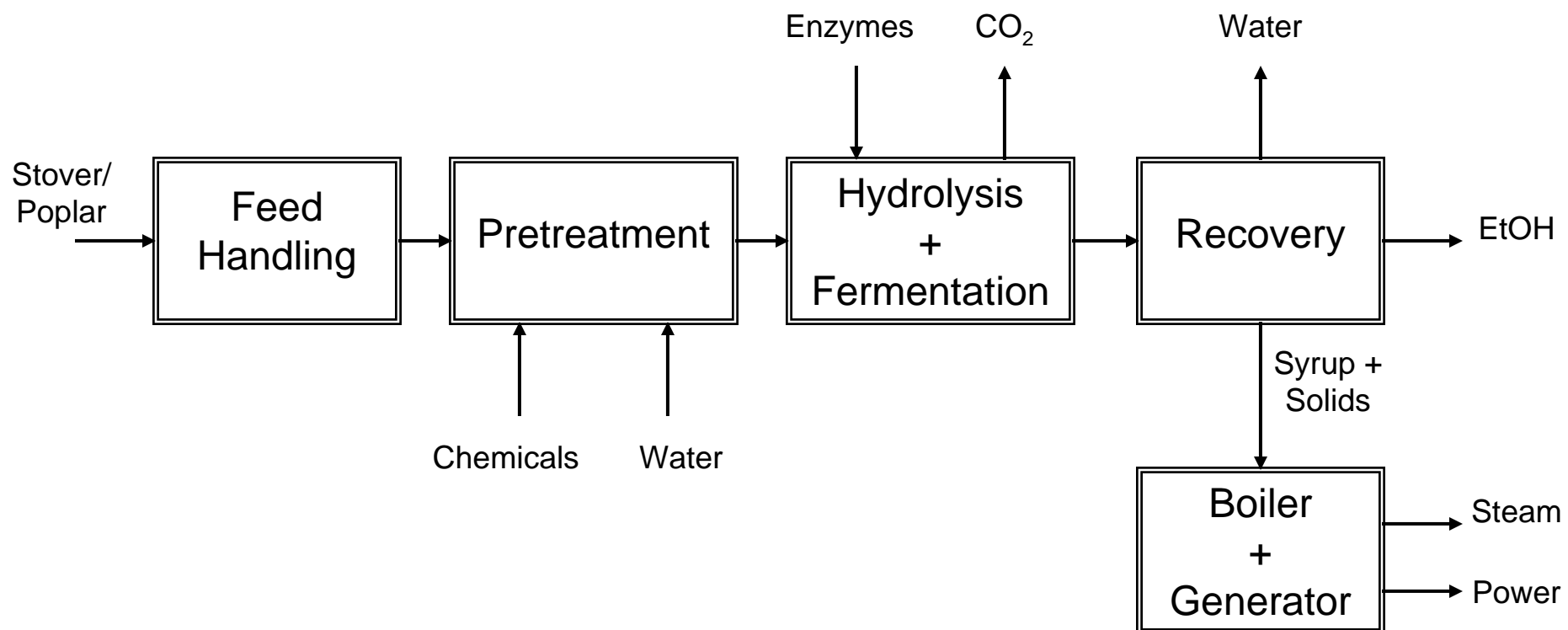
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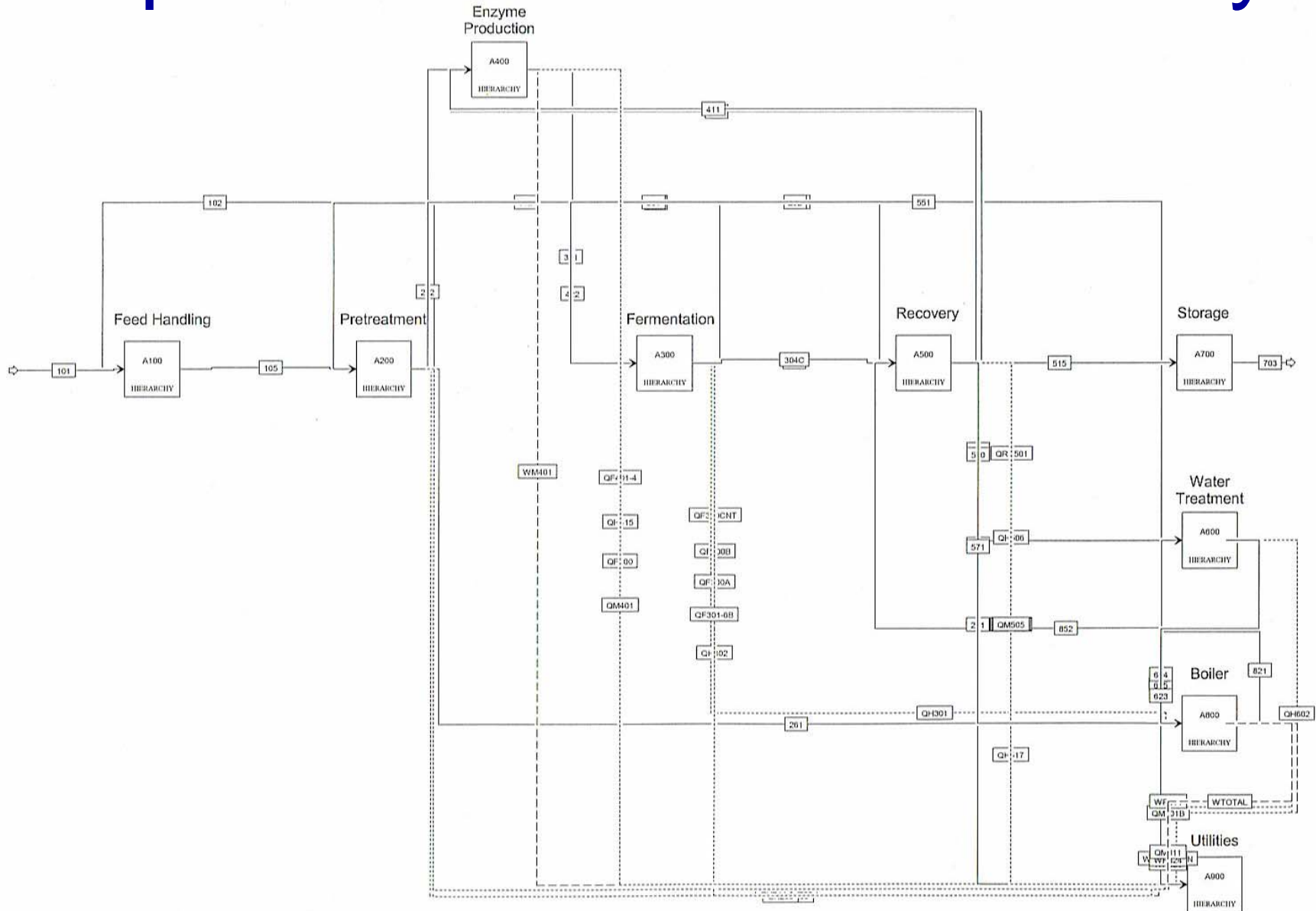
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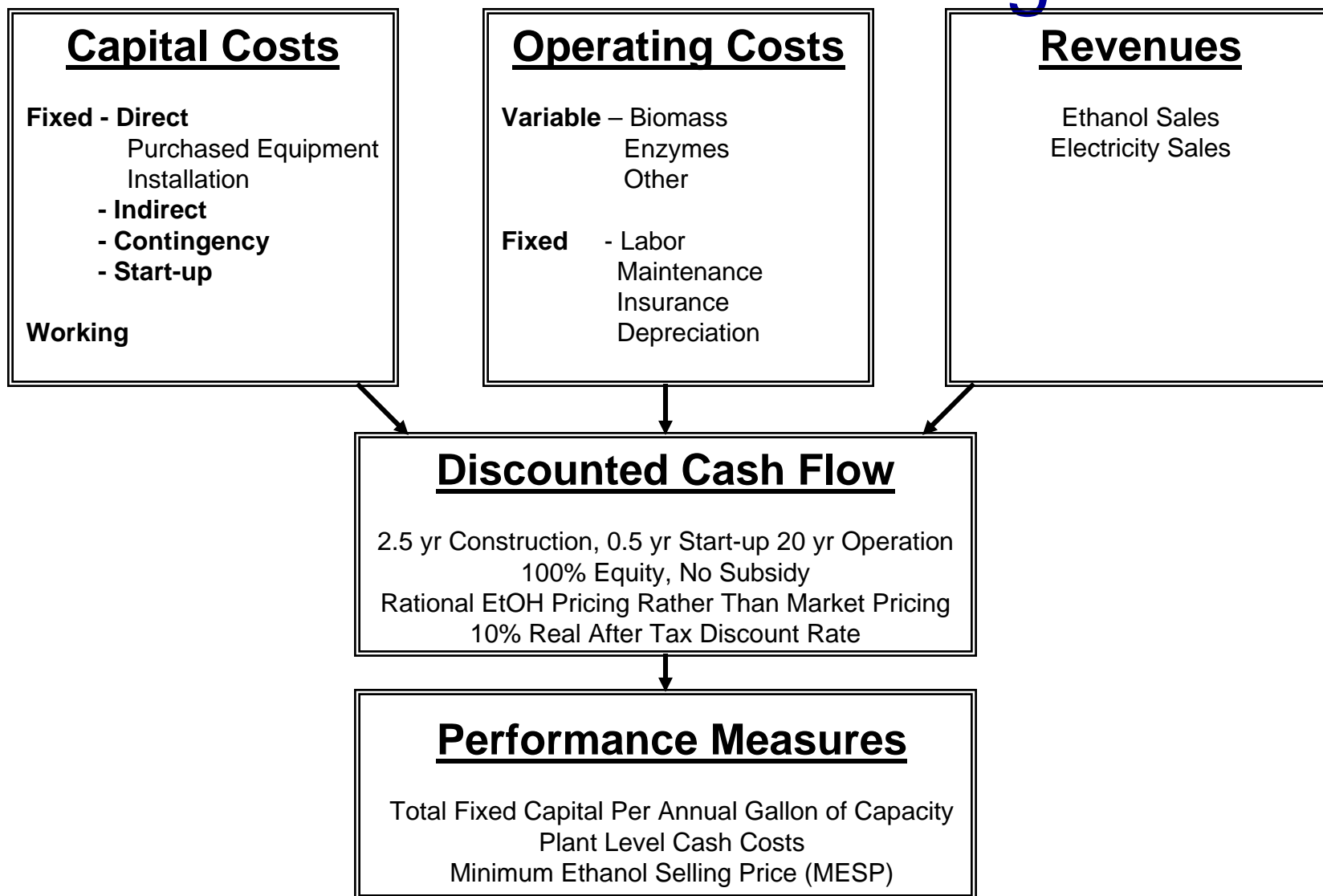
# Block Flow



# Aspen Plus – GUI w/ Hierarchy



# Economic Modeling



# Current vs. Goal

- Current: Laboratory Performance
  - Pretreatment
  - Conditioning
  - Enzymatic Hydrolysis
  - Fermentation
- Goal: Likely Performance of Above Steps at Commercial Scale

# Results (Interim)

MESP, \$/gal

	Stover			Poplar	
	<u>Current</u>	<u>Goal</u>		<u>Current</u>	<u>Goal</u>
Ideal Pretreatment	1.49	0.81	↔	1.42	0.77
Acidic	↕	↕	↔	↕	↕
Neutral pH					
Alkaline					
No Pretreatment	12.86	7.84	↔	36.73	19.63

# Case Study

- Poplar Goal Case - Ideal Pretreatment
- Sensitivities
  - Pretreatment+Hydrolysis Yield
  - Beer Concentration
  - Pretreatment Fixed Capital
  - Financial Assumptions
  - Other

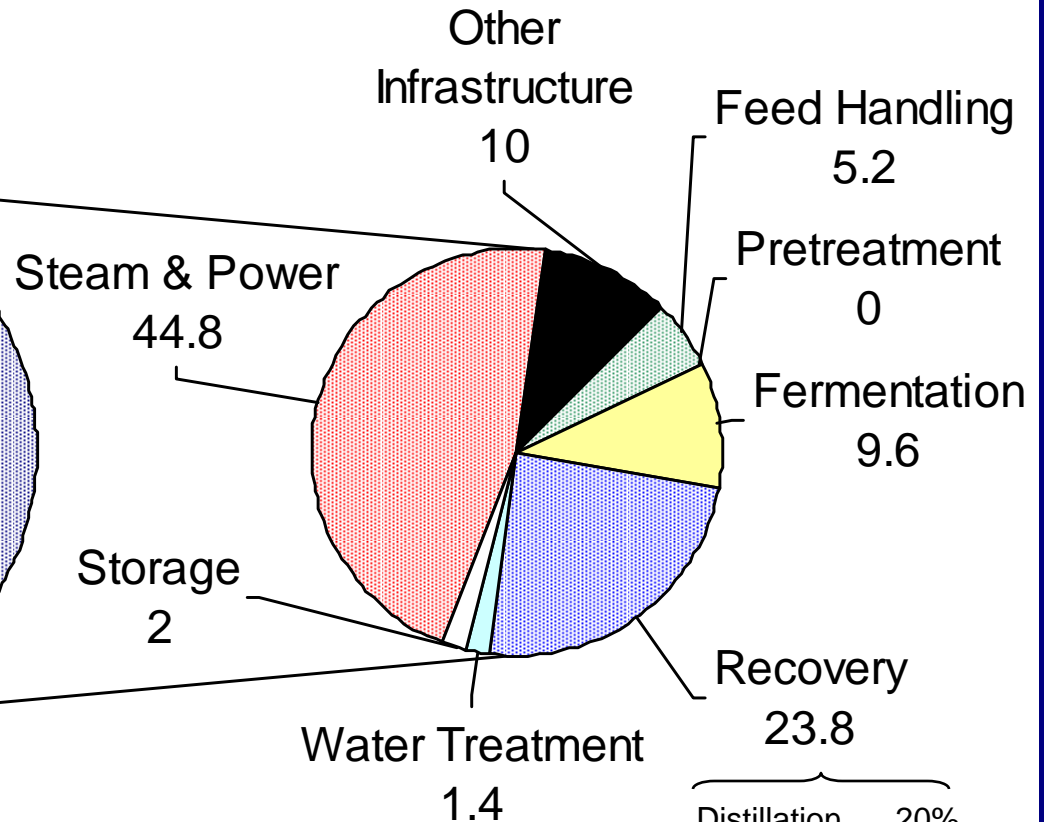
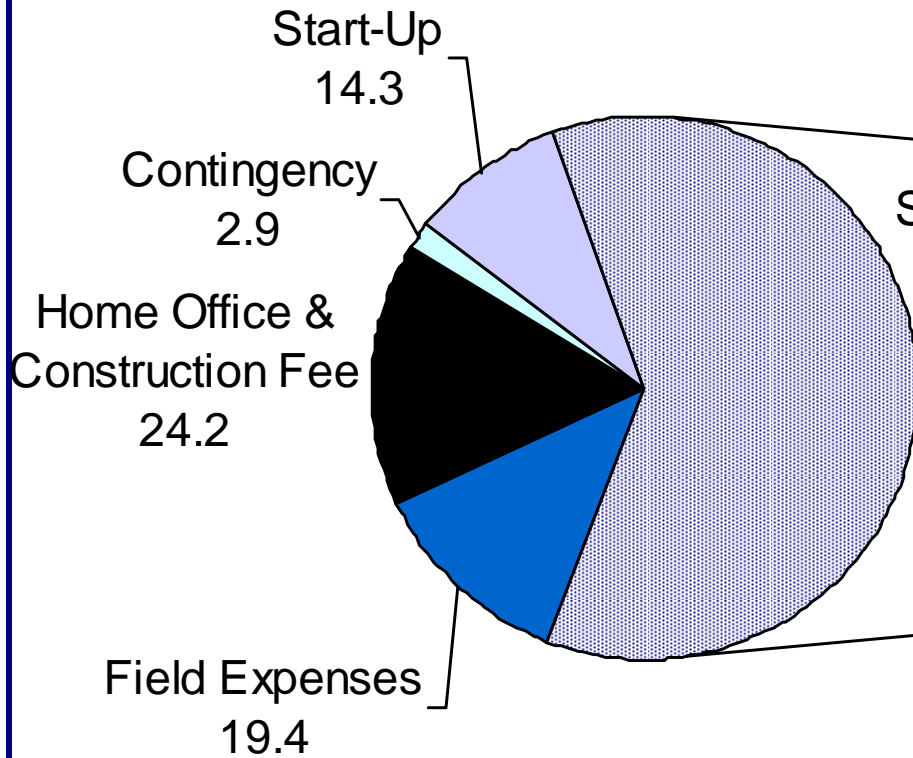
# Fixed Capital

Values are \$MM (US Location, 2002)

Biomass  
CAF<sub>2</sub>  
Refining

## Total Fixed

## Direct Fixed



	\$MM
Direc	96.8
Indirects	<u>60.8</u>
Total	157.6

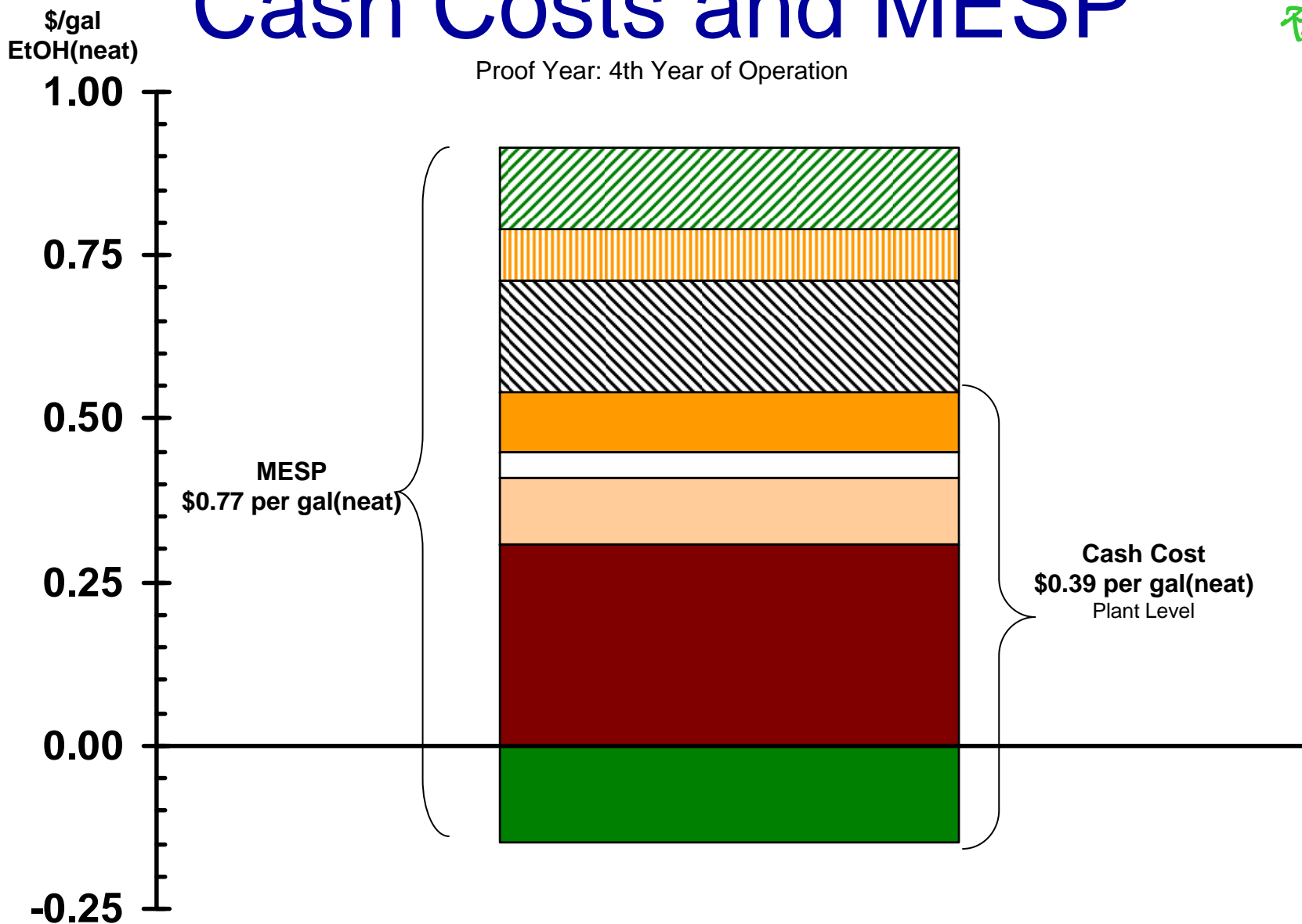


$157.6 / 75.7 = \$2.08$   
per annual gal(neat)  
Actual Goal Cases have  
\$2.50-\$3.50 per annual gal (neat)

Distillation	20%
Evaporation	65%
Mole Sieve	14%
Vent Scrubber	1%

# Cash Costs and MESP

Proof Year: 4th Year of Operation

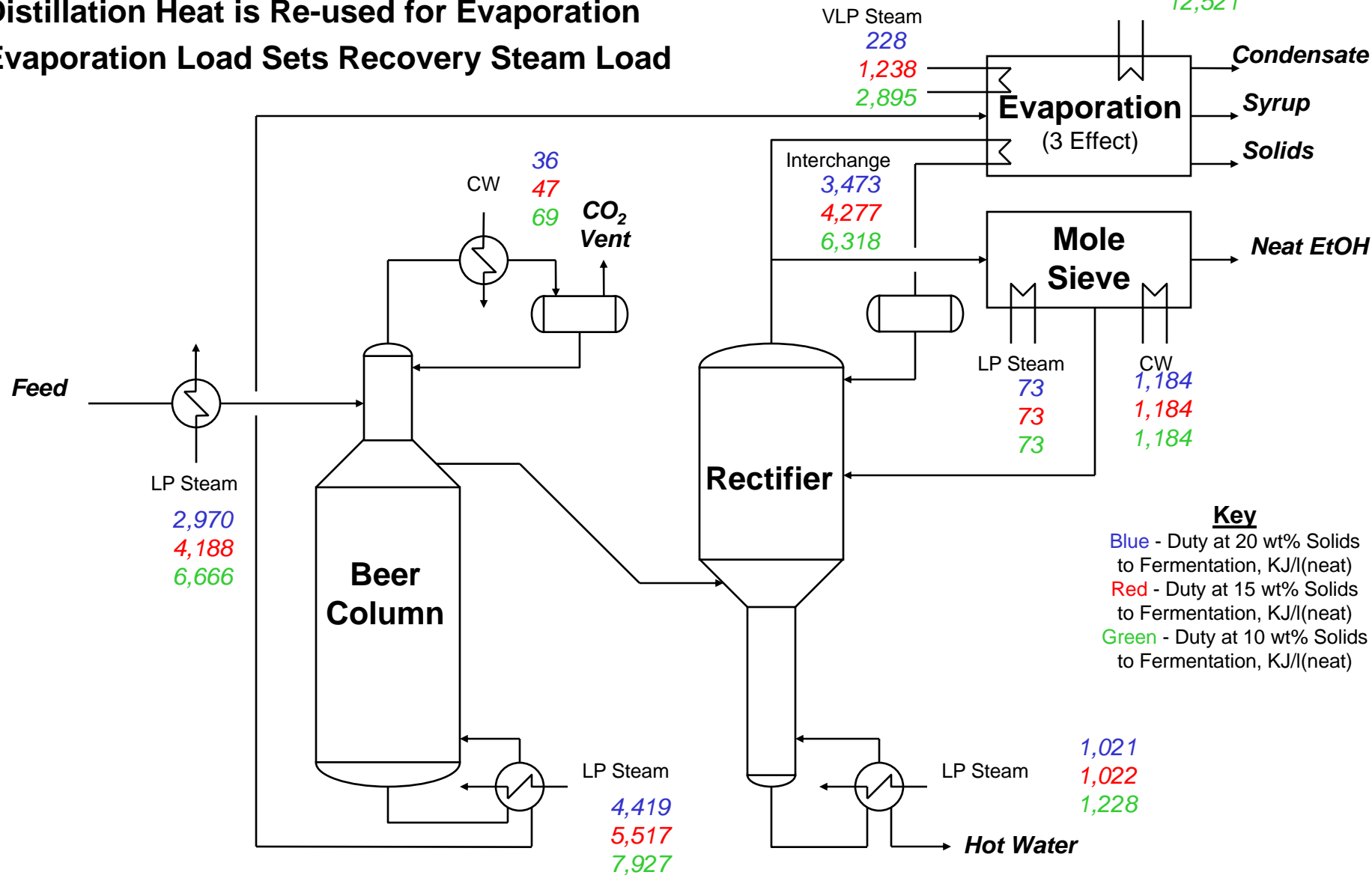


- |                          |                |              |                     |
|--------------------------|----------------|--------------|---------------------|
| ■ Electricity Coproduct  | ■ Feedstock    | ■ Enzymes    | □ Other Variable    |
| ■ Fixed w/o Depreciation | ■ Depreciation | ■ Income Tax | ■ Return on Capital |

# Recovery

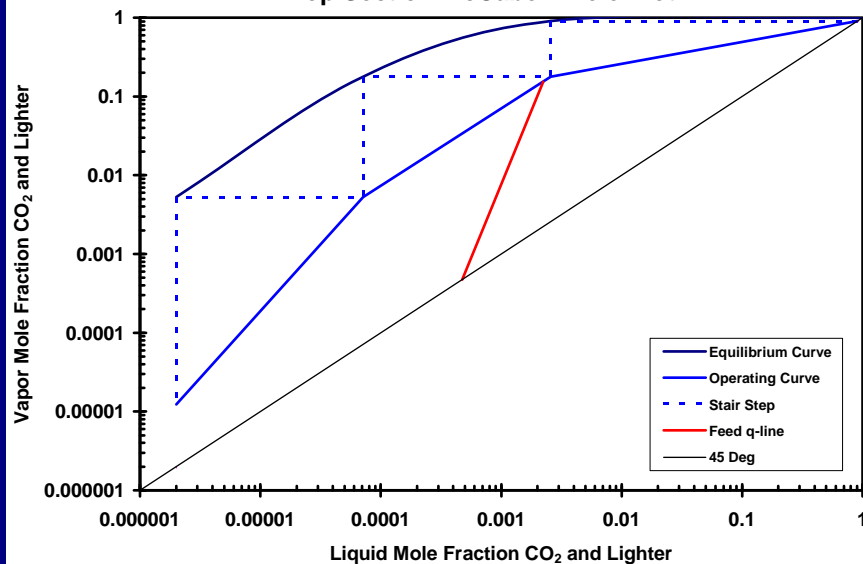
Distillation Heat is Re-used for Evaporation  
Evaporation Load Sets Recovery Steam Load

Biomass  
CAFJ  
Refining

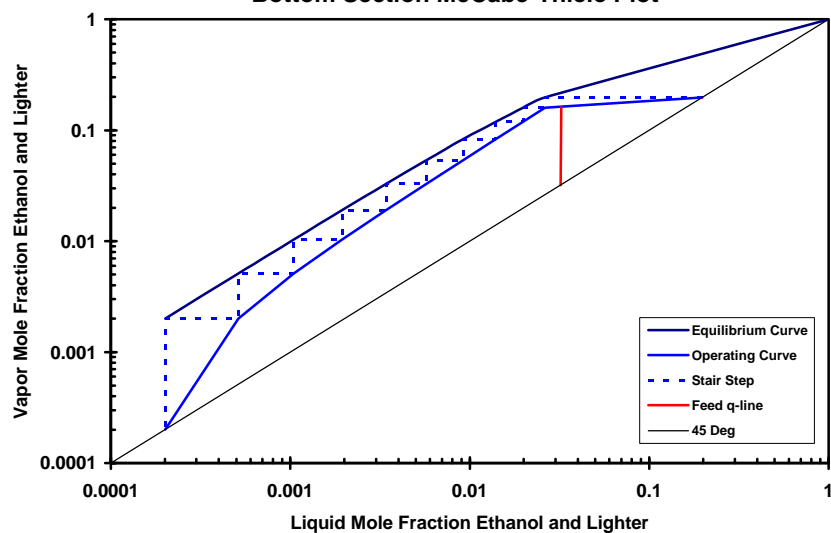


# Beer Column

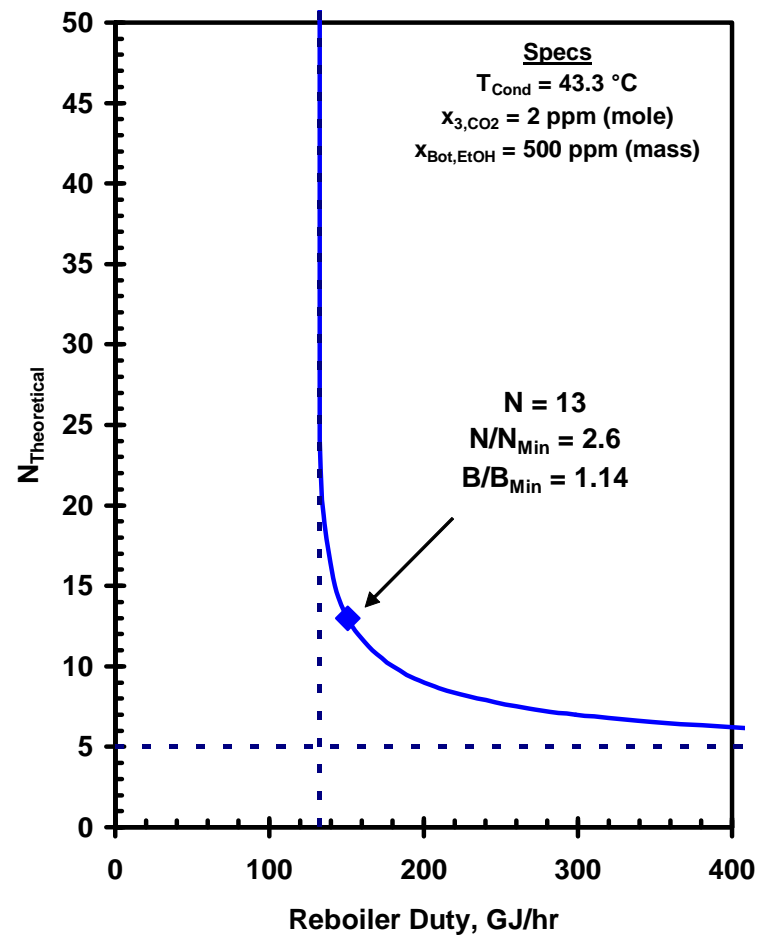
Top Section McCabe-Thiele Plot



Bottom Section McCabe-Thiele Plot

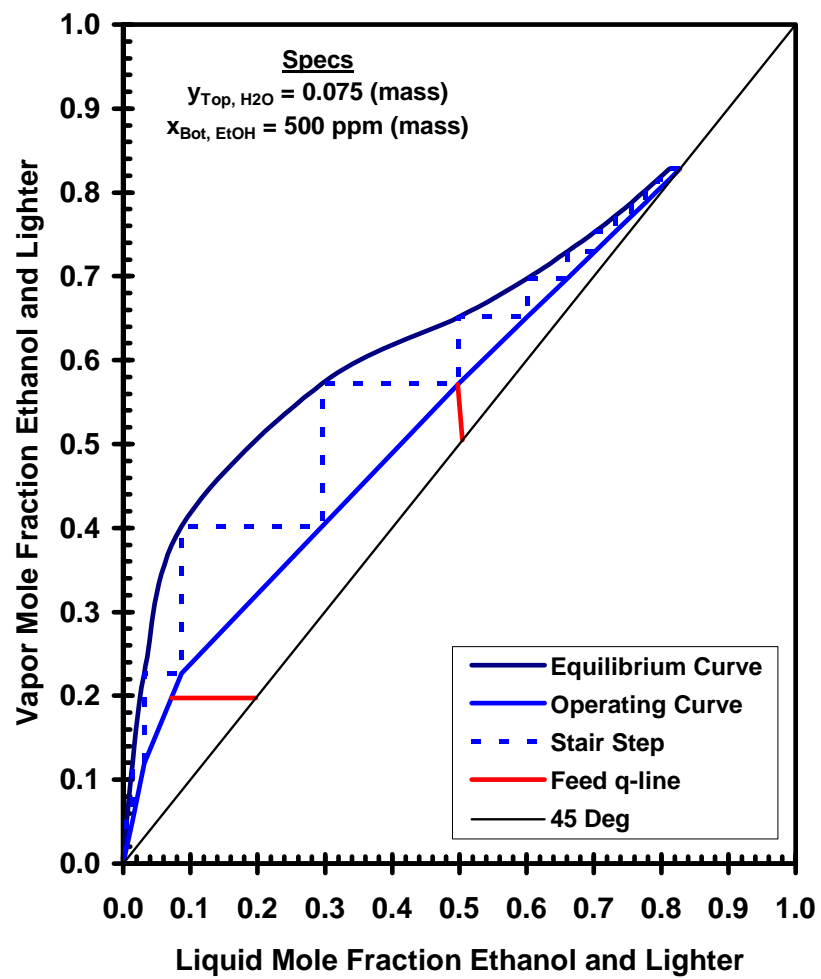


Theoretical Stages vs. Reboiler Duty

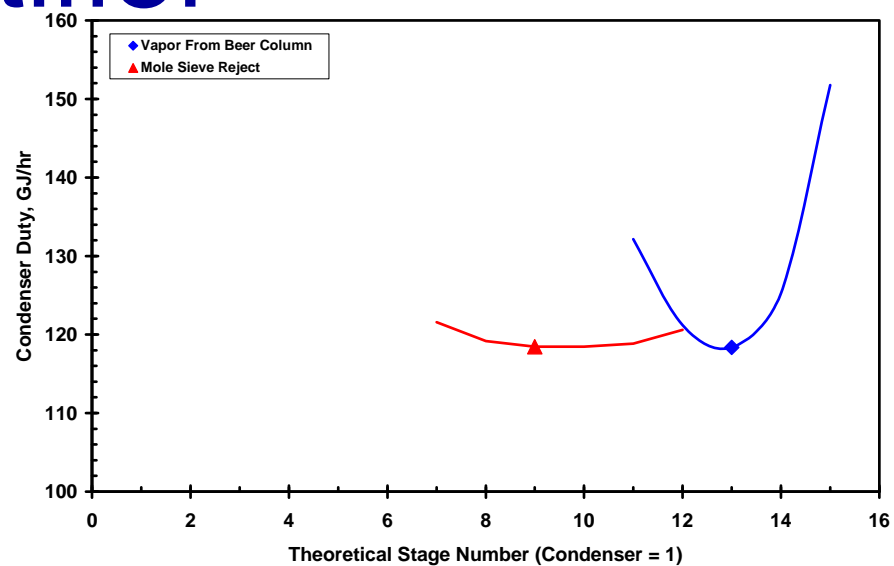


# Rectifier

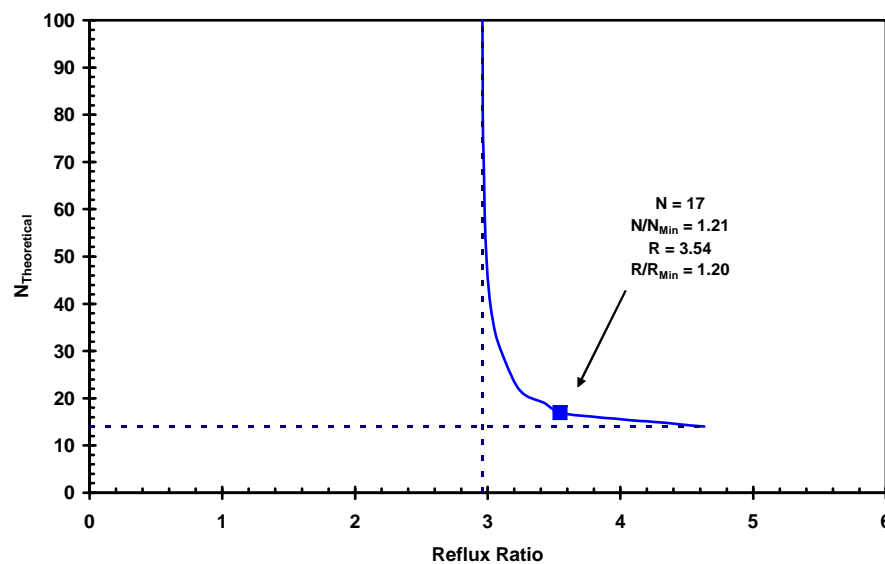
McCabe-Thiele Plot



Feed Stage Optimization



Theoretical Stages vs. Reflux Ratio

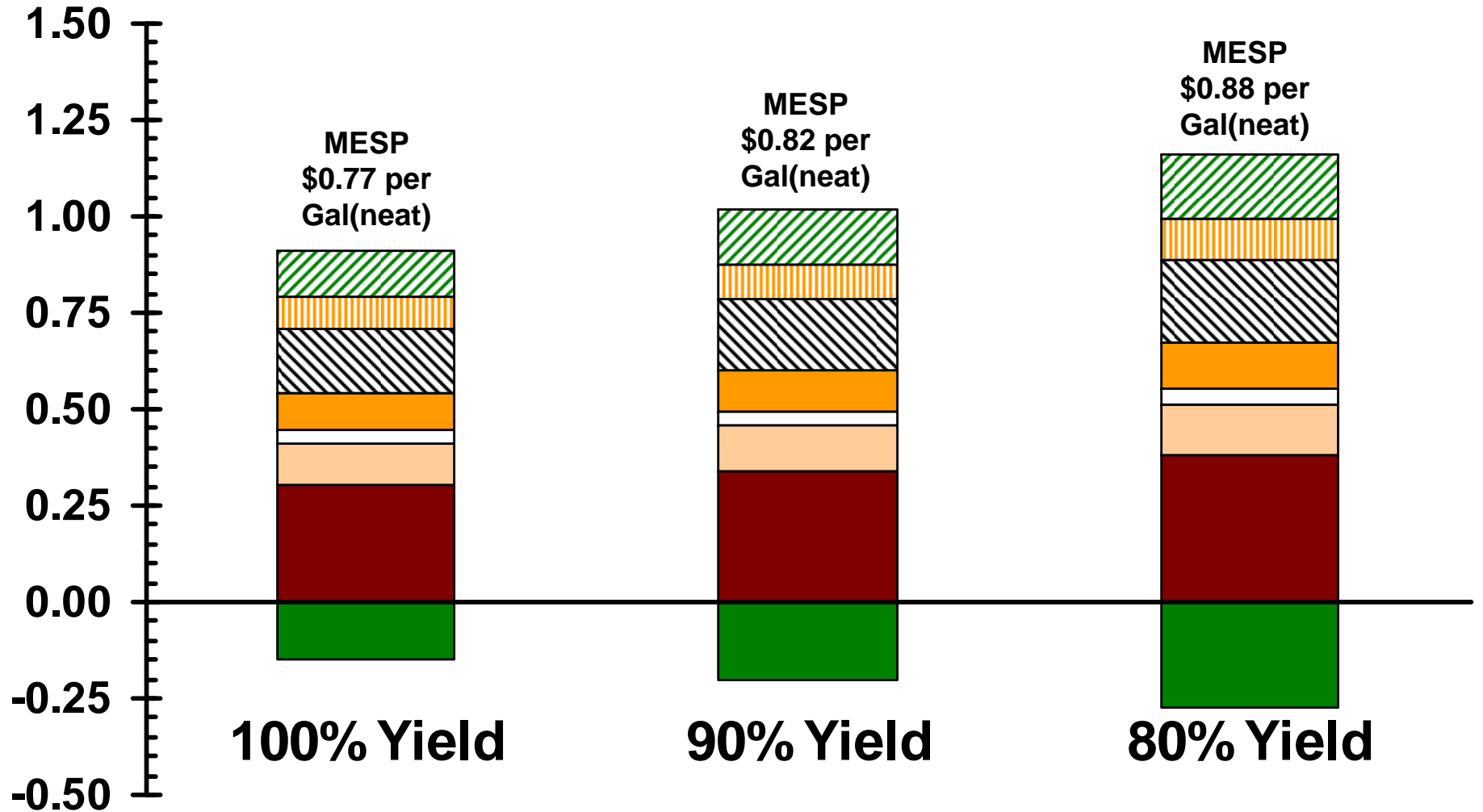


# Pretreatment+Hydrolysis Yield

Biomass  
CAFD  
Refining

At Constant EtOH Concentration to Recovery,  $z_{EtOH} = 0.066$  (mass, liquid)

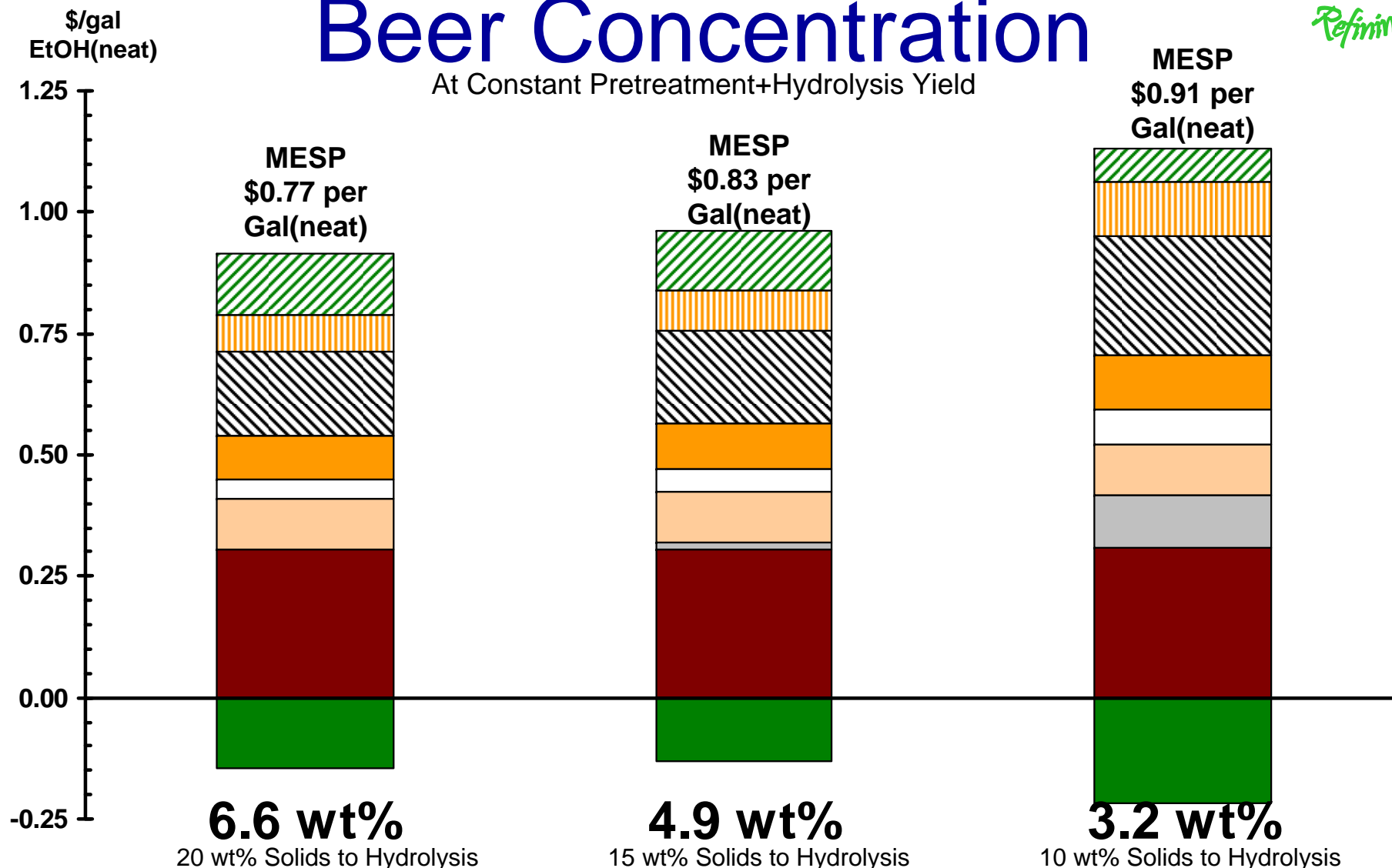
\$/gal  
EtOH(neat)



- Electricity Coproduct    ■ Feedstock    ■ Enzymes    □ Other Variable
- Fixed w/o Depreciation    ■ Depreciation    ■ Income Tax    ■ Return on Capital

# Beer Concentration

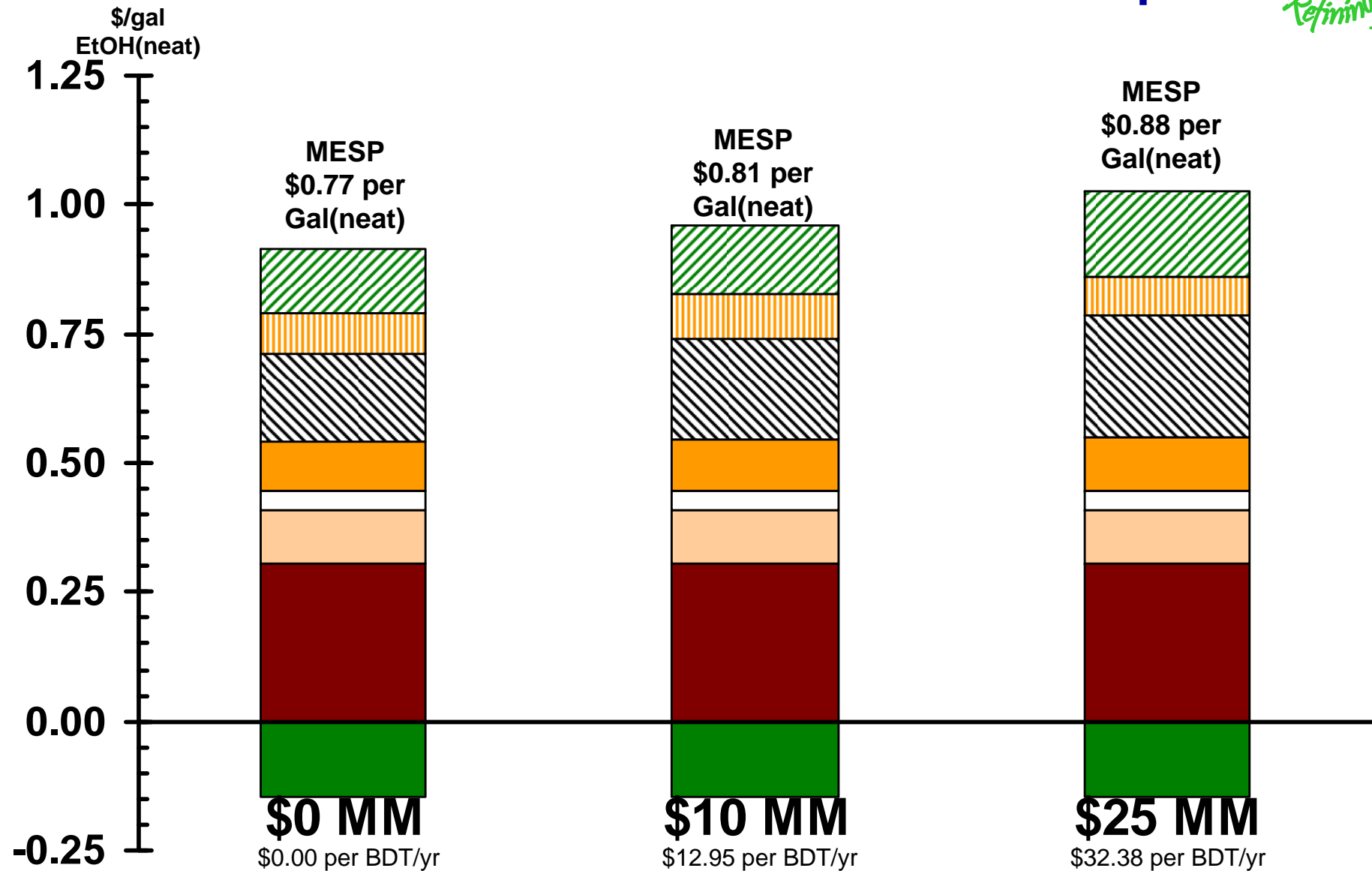
At Constant Pretreatment+Hydrolysis Yield



- Electricity Coproduct
- Feedstock
- Supplemental Feed
- Enzymes
- Other Variable
- Fixed w/o Depreciation
- Depreciation
- Income Tax
- Return on Capital

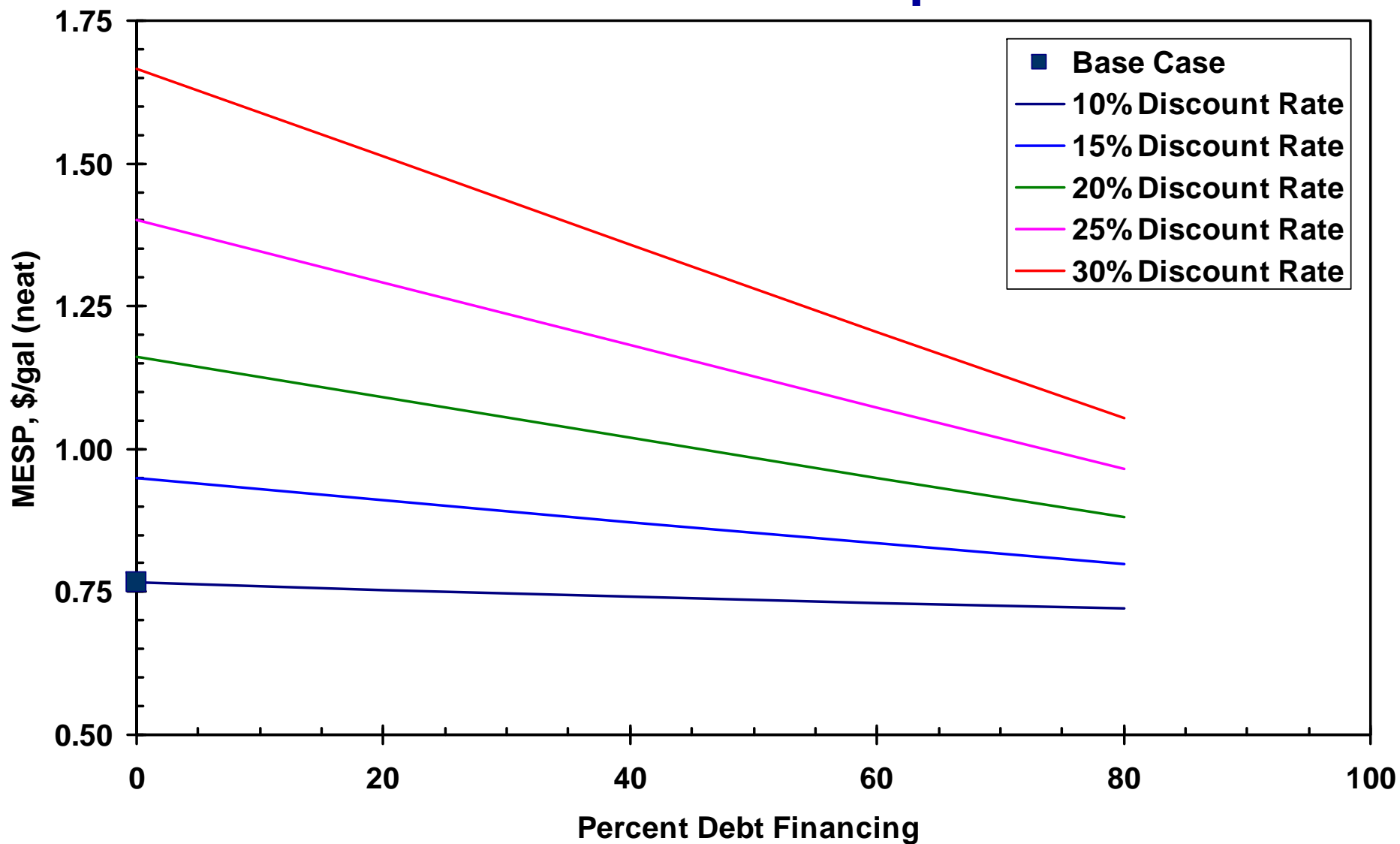
# Pretreatment Direct Fixed Capital

Biomass  
CAF<sub>2</sub>  
Refining



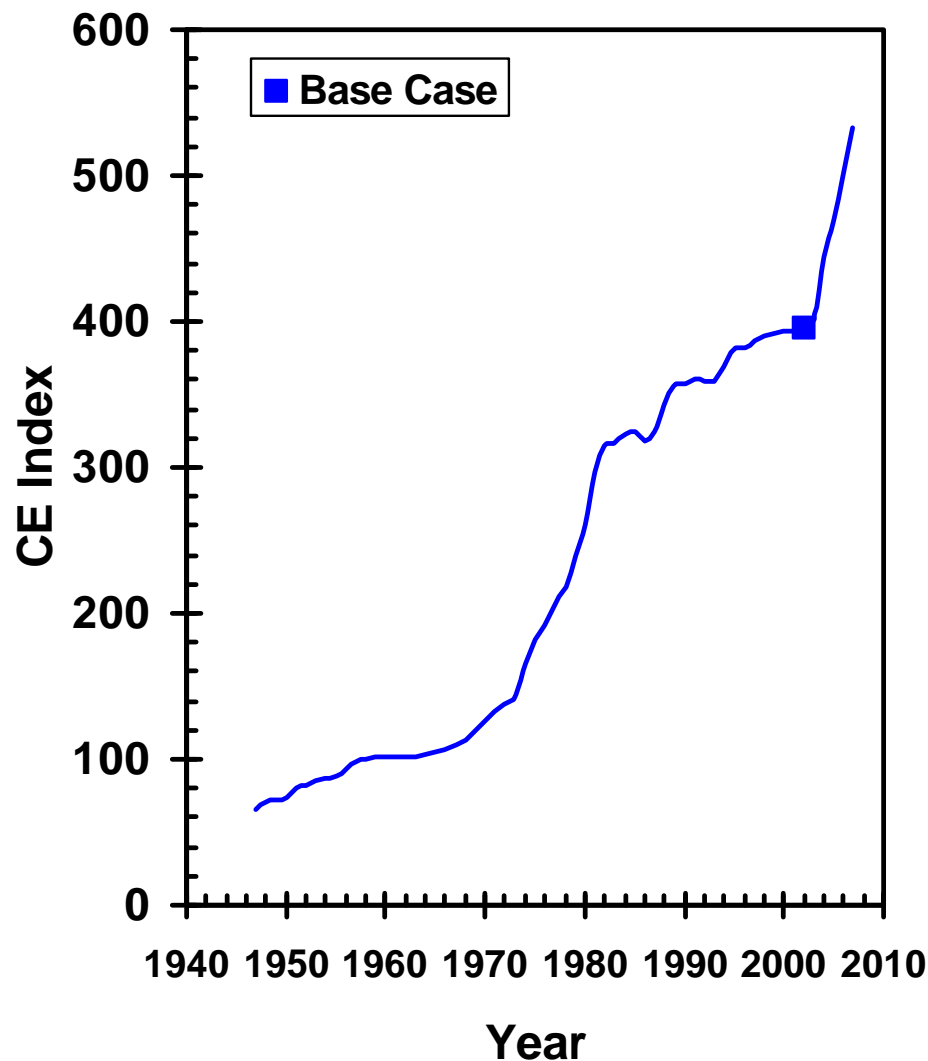
- Electricity Coproduct    ■ Feedstock    □ Enzymes    □ Other Variable
- Fixed w/o Depreciation    ▨ Depreciation    ■ Income Tax    ▨ Return on Capital

# Financial Assumptions

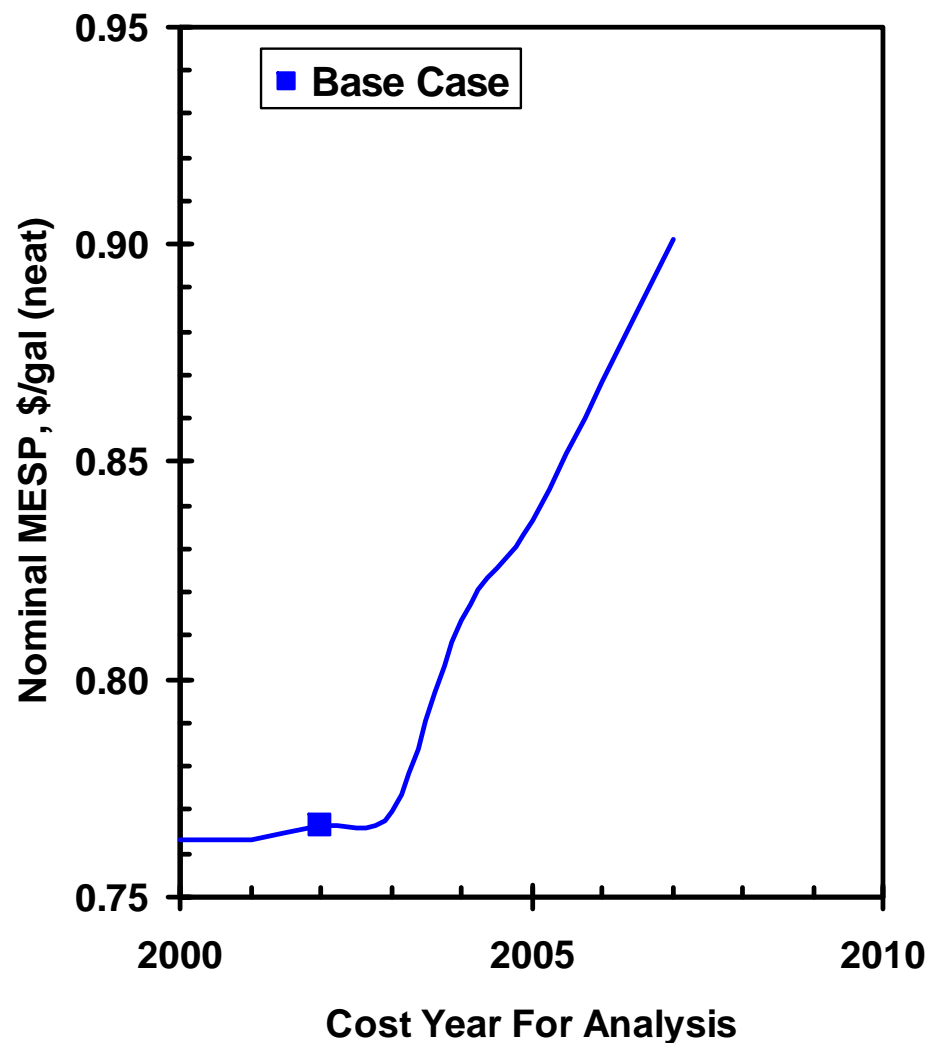


# Financial Assumptions

## Inflation - Chemical Equipment



## Effect of Inflation



# Other Assumptions

- Feedstock Price
  - Basis: \$30 per BDT
  - Direct Impact on MESP and Cash Costs
- Enzyme Price/Usage
  - Basis: ~\$0.10 per gal EtOH (neat)
  - Direct Impact on MESP and Cash Costs
- Lignin Solubilization
  - Negligible Impact on MESP and Cash Costs
- Utilities
  - Incremental Steam: \$3.13 per 1000 lbs
  - Power: \$0.04 per KWh (2007 Dollars)

# Conclusions

- Consistent Methods
- Pretreatment Related Cost Drivers
  - Hydrolysis Yield
  - Solids Concentration to Hydrolysis
- Non-Pretreatment Cost Drivers are Also Important
- Sensitivity Analysis for Useful Bounds

# Acknowledgements

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- Biomass Refining Consortium for Applied Fundamentals and Innovation (CAFI)
- Natural Resources Canada
- Genencor International

# Project Institutions

