National Renewable Energy Laboratory
Innovation for Our Energy Future

Integrating and Piloting Lignocellulose Biomass Conversion Technology

Advanced Biofuels Workshop/Fuel Ethanol Workshop

Daniel J. Schell

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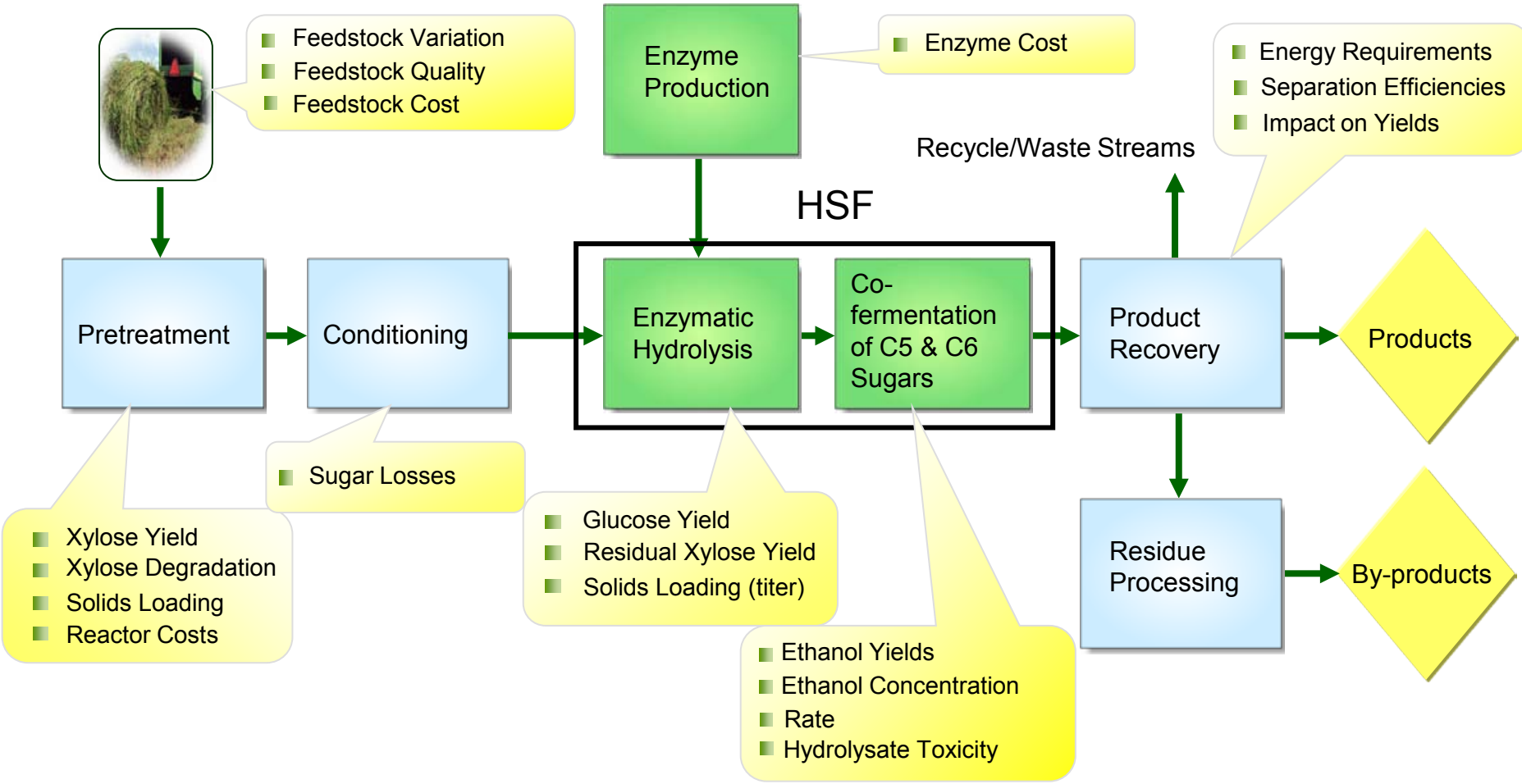
NREL Process Integration Project Goals

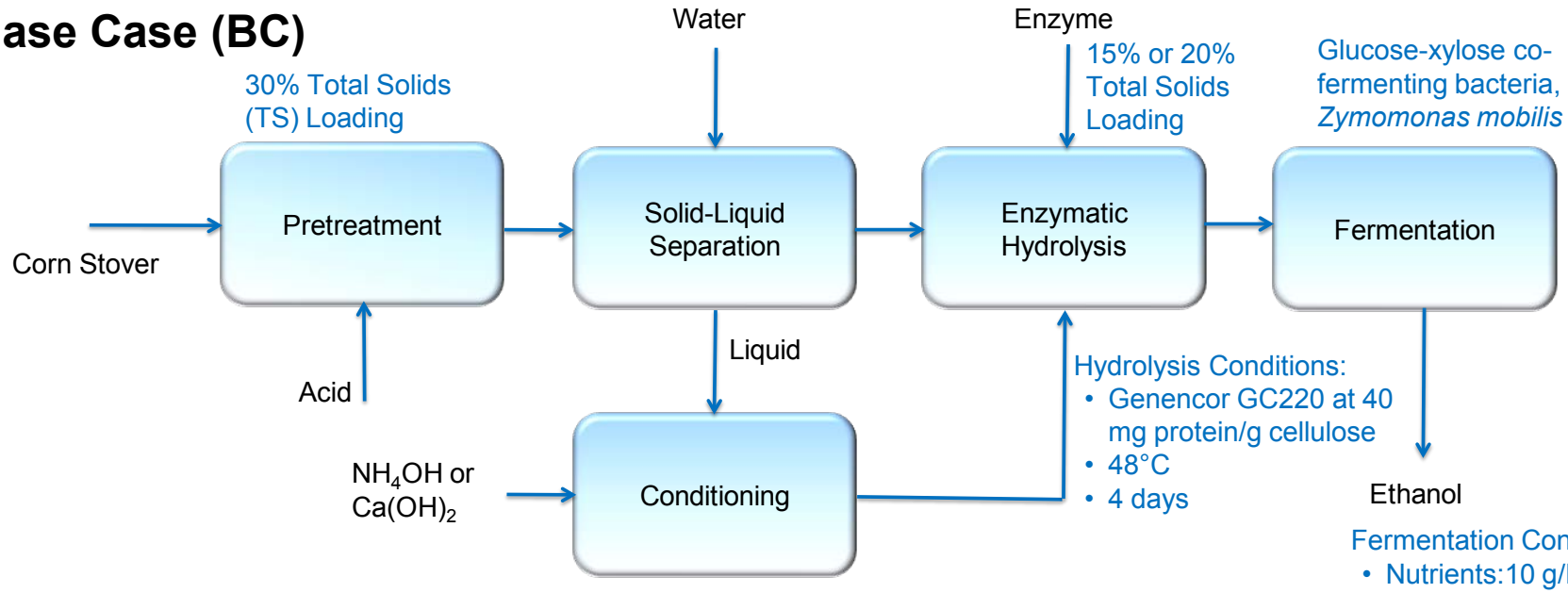
- Investigate bioethanol production technology at the bench and pilot scales using corn stover
- Produce integrated pilot-scale performance data, which when combined with a process design and a cost estimate validates a $1.49 (2007$) per gallon ethanol selling price

Key Process Performance Issues



Process Configurations Investigated

Base Case (BC)



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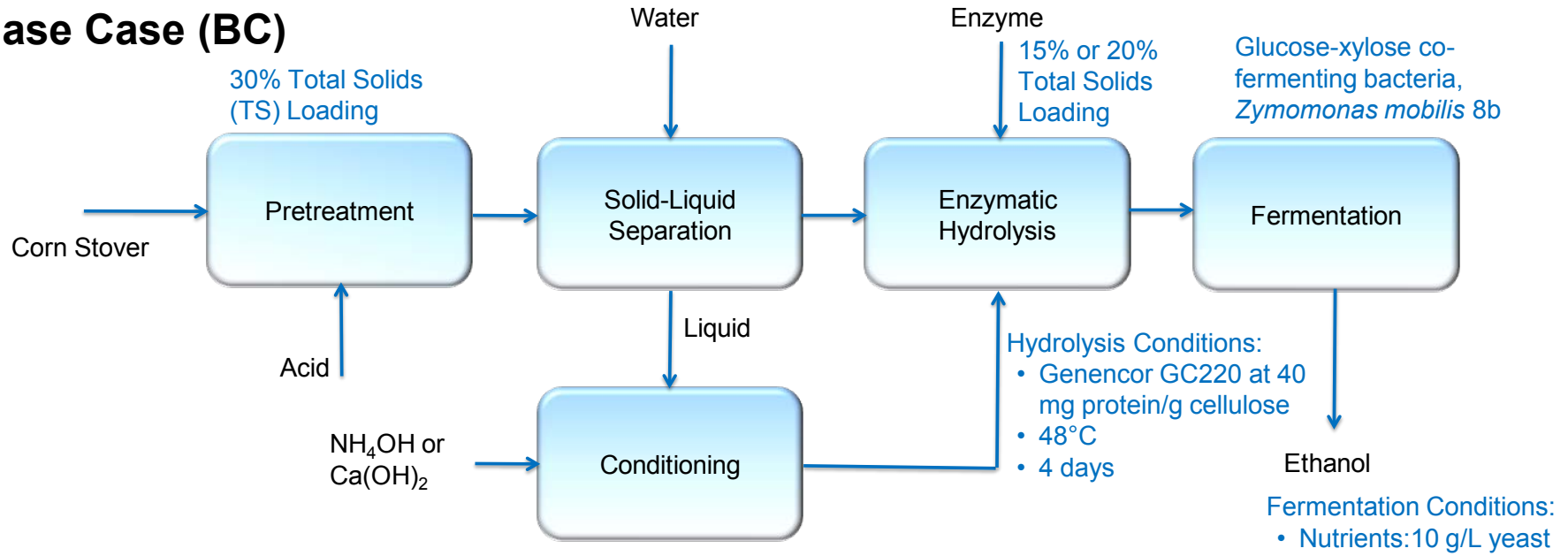
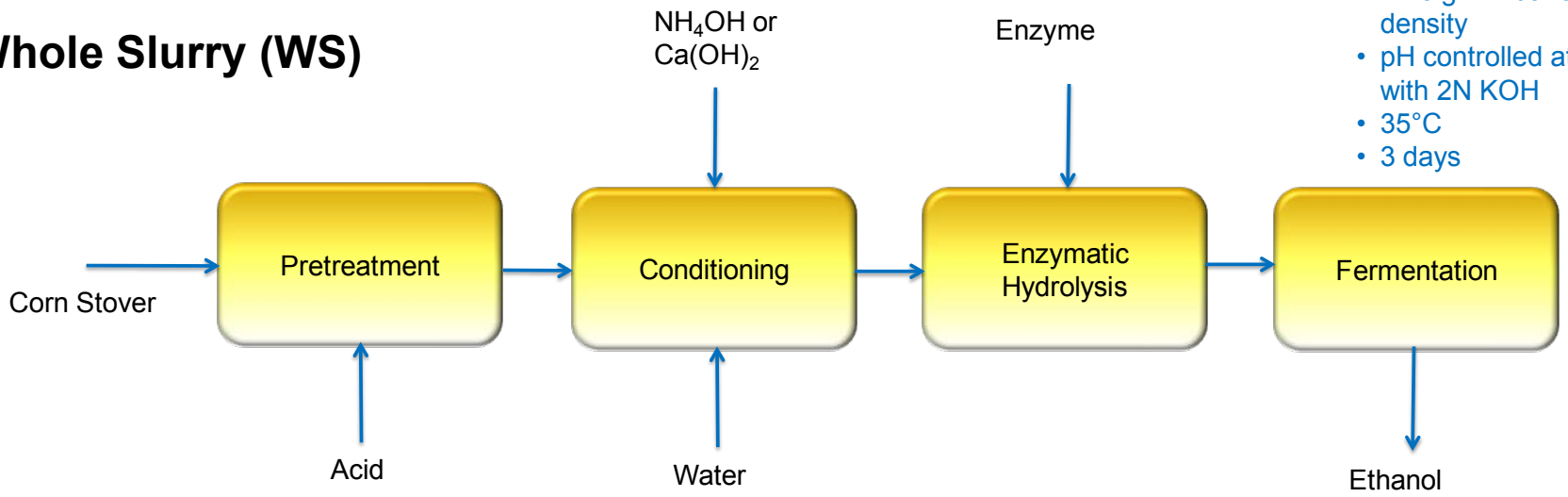
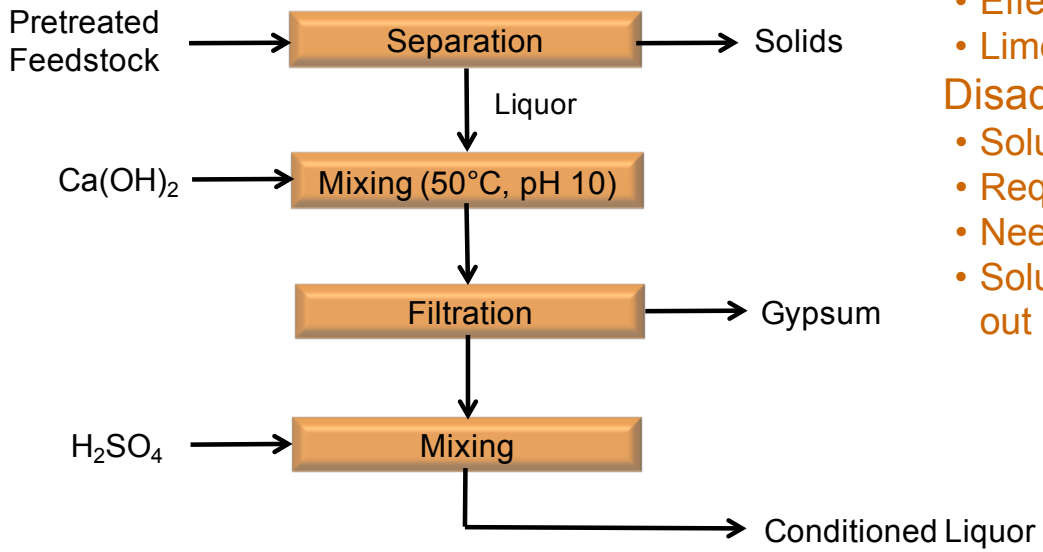


Whole Slurry (WS)



Conditioning Technologies

Overliming Process (OL)



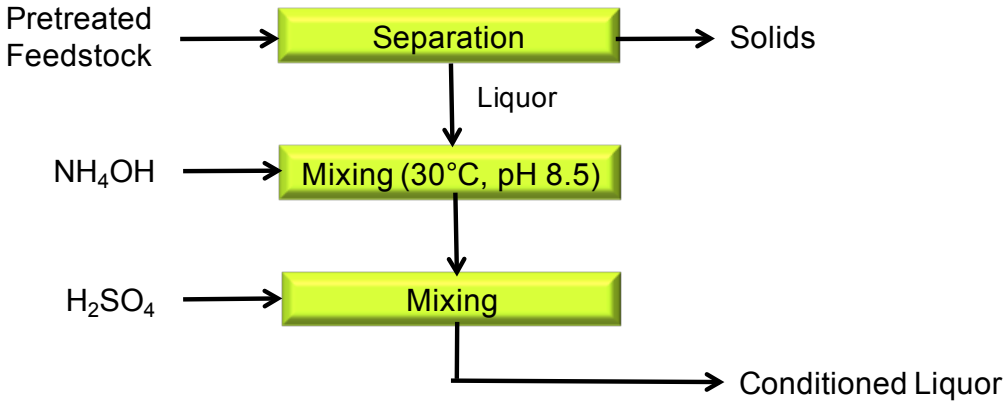
Advantages:
- Effectively detoxifies dilute acid (DA) hydrolysates
- Lime is inexpensive

Disadvantages:
- Soluble sugars are lost/degraded
- Requires additional filtration step to remove gypsum
- Need to dispose of insoluble gypsum
- Soluble gypsum remains in solution and can plate out in downstream equipment

Advantages:
- Effectively detoxifies DA hydrolysates
- No sugar degradation
- Insoluble solids are not produced

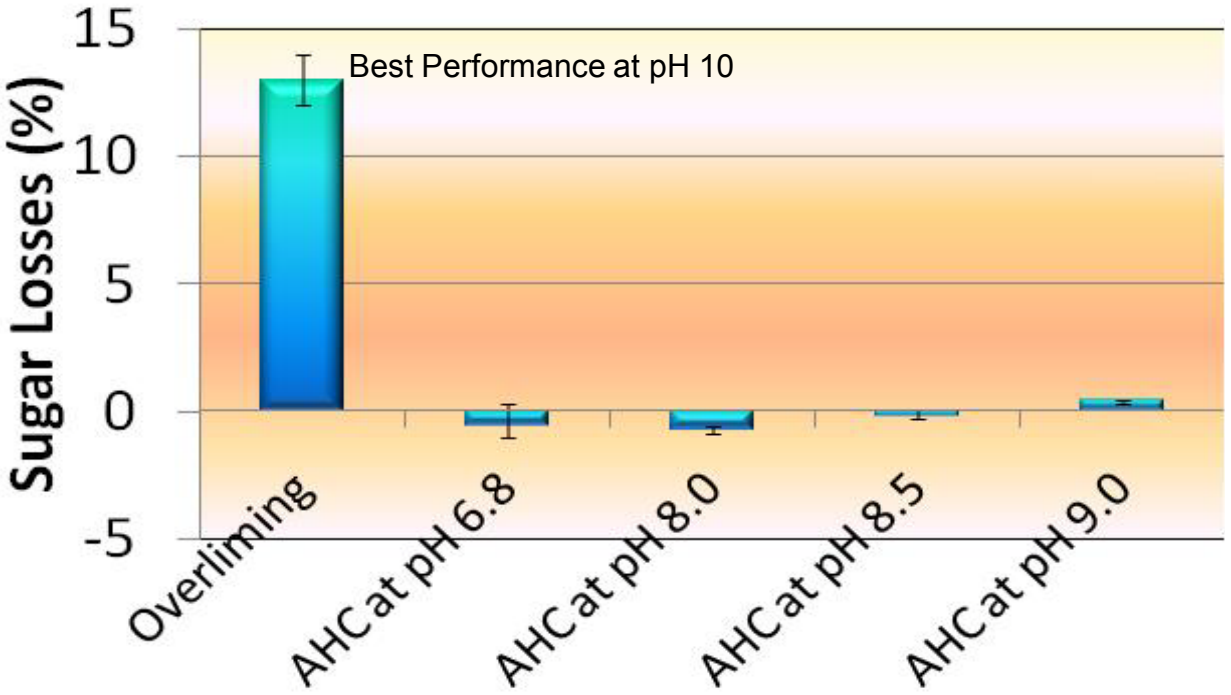
Disadvantages:
- NH_4OH is expensive
- High ammonia salt concentrations are left in the treated liquor

Ammonium Hydroxide Conditioning (AHC)



Conditioning Sugar Losses

Ammonium Hydroxide Conditioning eliminates sugar losses during conditioning of dilute acid pretreated corn stover hydrolysates



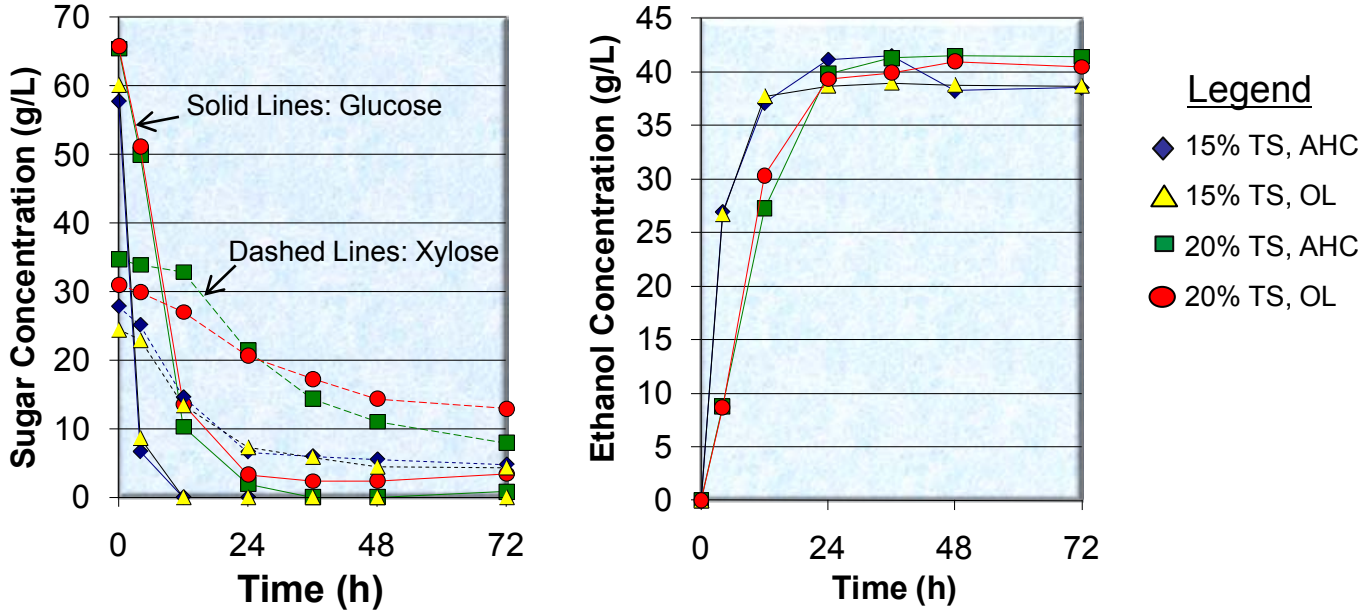
Integrated Performance Results

Pilot scale production of pretreated corn stover

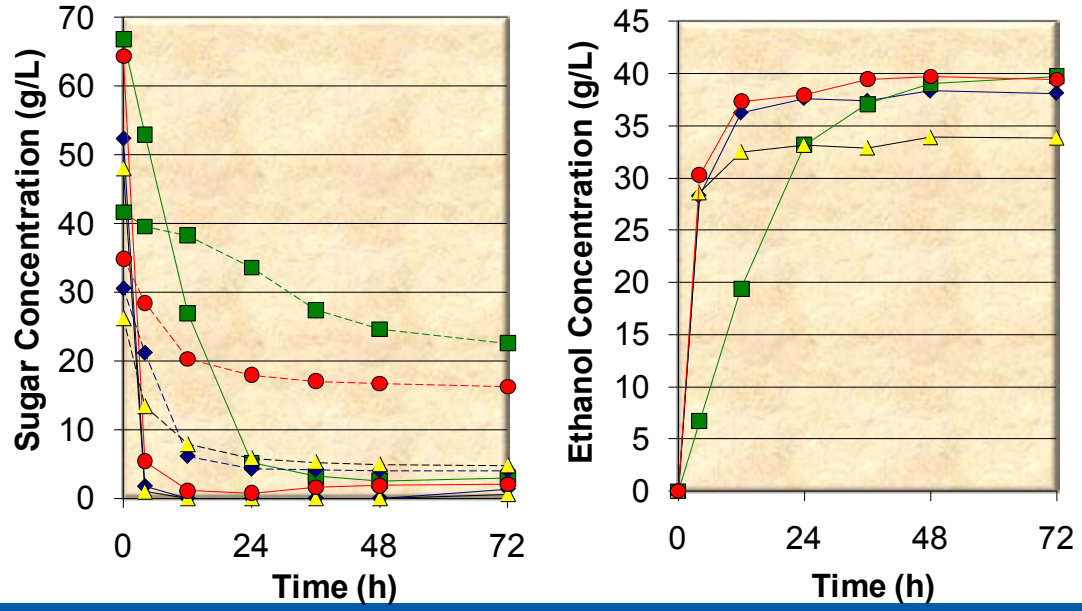
Bench scale conditioning, enzymatic hydrolysis and fermentation

Fermentation Data

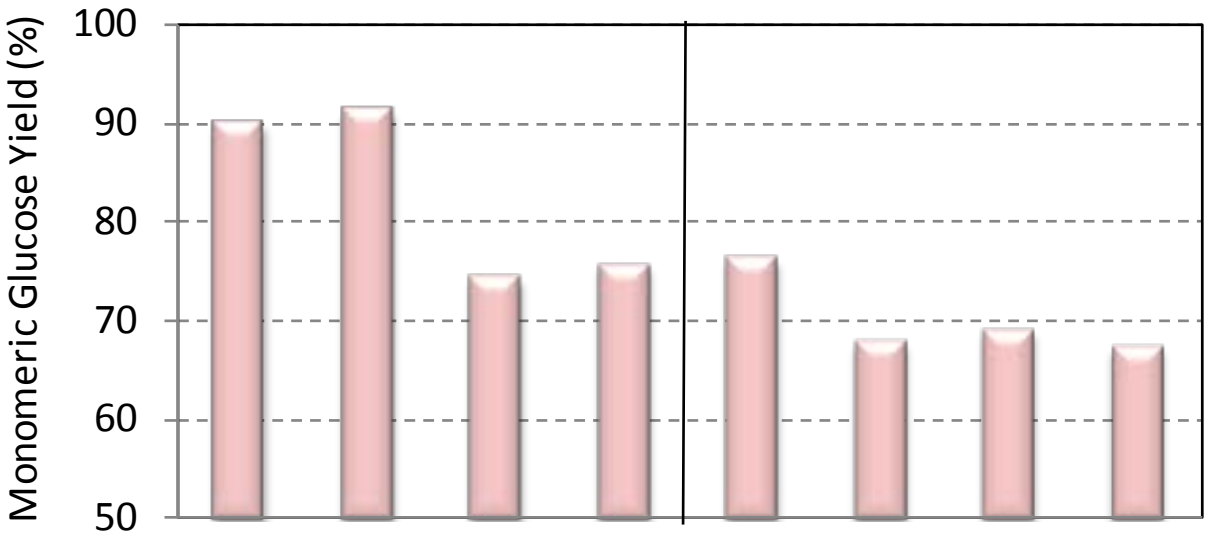
Base Case Process



Whole Slurry Process



Enzymatic Cellulose Hydrolysis

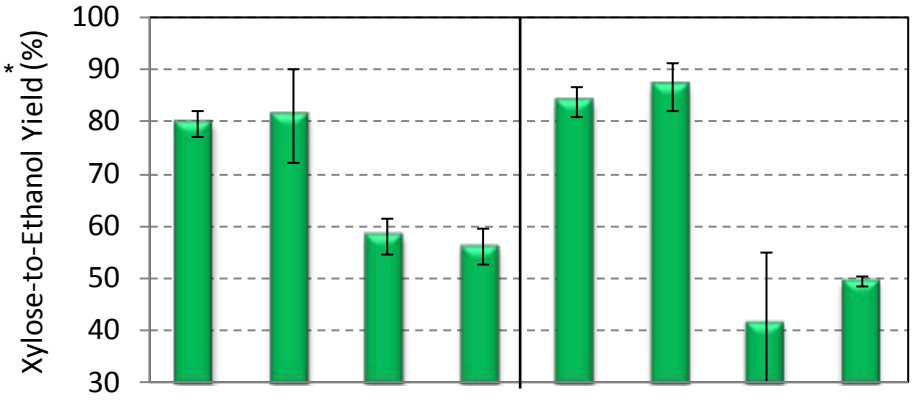


Process Configuration:	BC	BC	BC	BC	WS	WS	WS	WS
Total Solids Loading (%):	15%	15%	20%	20%	15%	15%	20%	20%
Conditioning Technology:	AHC	OL	AHC	OL	AHC	OL	AHC	OL

Key Results:

- Cellulose to monomeric glucose yields improve at lower solids loadings
- Yields are independent of conditioning technology
- Yields are lower for the whole slurry process

Conversion of Sugars to Ethanol



Process Configuration:	BC	BC	BC	BC	WS	WS	WS	WS
Total Solids Loading (%):	15%	15%	20%	20%	15%	15%	20%	20%
Conditioning Technology:	AHC	OL	AHC	OL	AHC	OL	AHC	OL

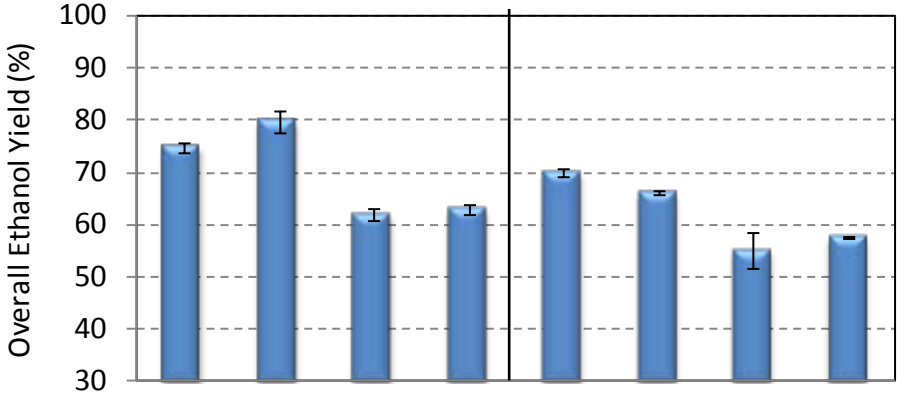
*Assumes 90% glucose to ethanol yield

Xylose to Ethanol Yields:

- Yields are lower at high solids loadings
  - Higher inhibitor concentrations
  - Higher ethanol concentrations
- Conditioning technology and process configuration have little impact

Overall Ethanol Yield:

- Base case process configuration outperforms whole slurry process configuration
- Conditioning technology has little impact on overall conversion yields



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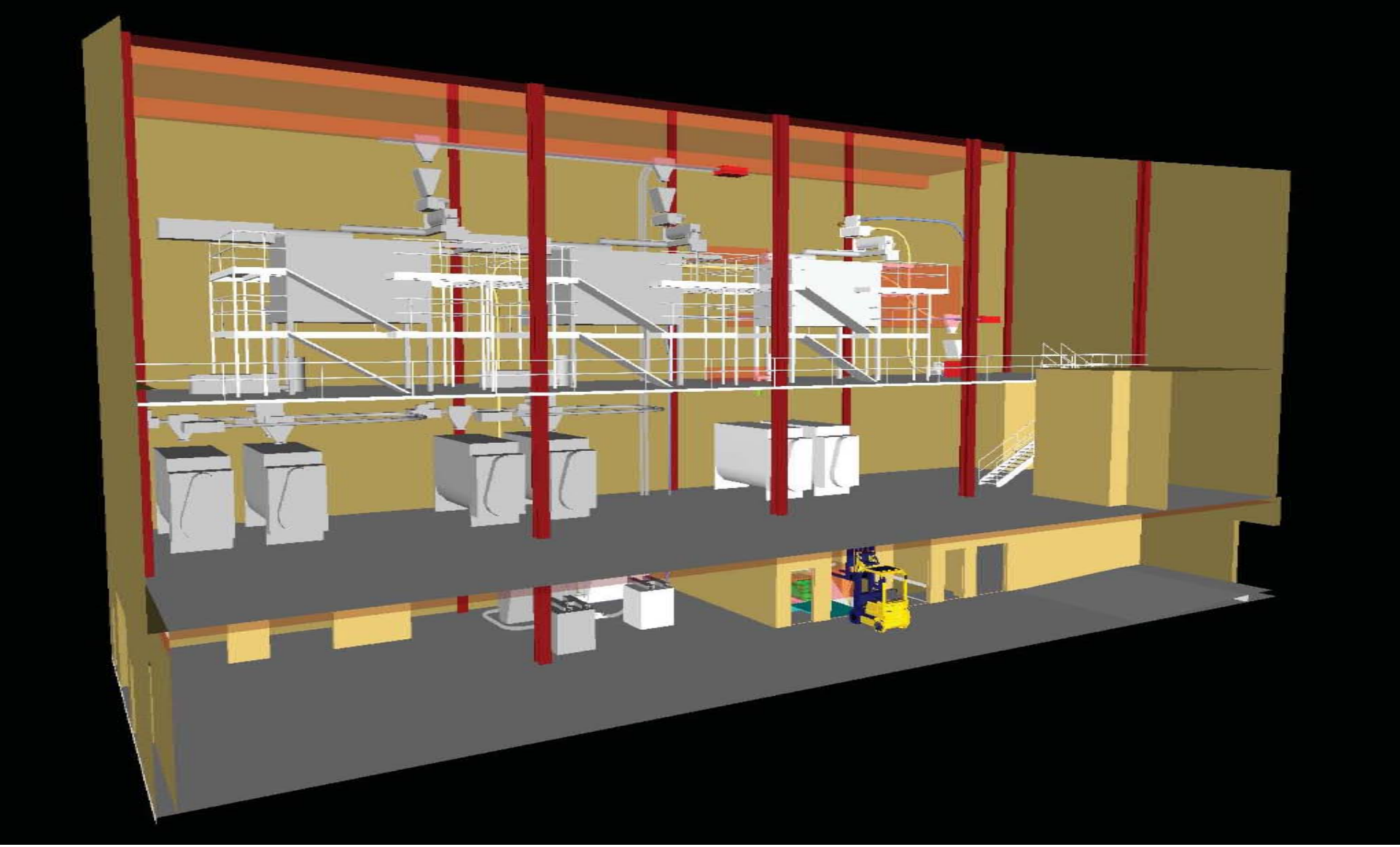
Constructing New Pilot Plant Capabilities

- Pilot plant expansion planned for substantial completion by May 2010
- New Equipment: Feedstock milling/handling system, versatile pretreatment systems, high solids enzymatic hydrolysis reactors
- Designed for parallel processing and flexible reconfiguration of unit operations with space for future equipment



Mortenson construction

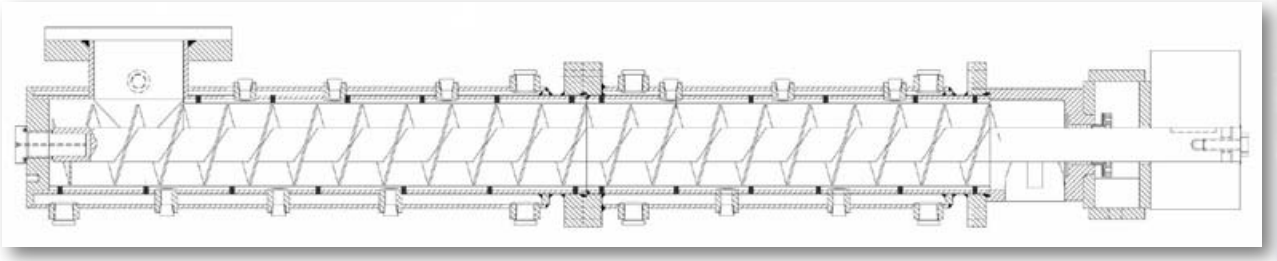
H+L architecture

MERRICK BUILDING QUALITY SOLUTIONS

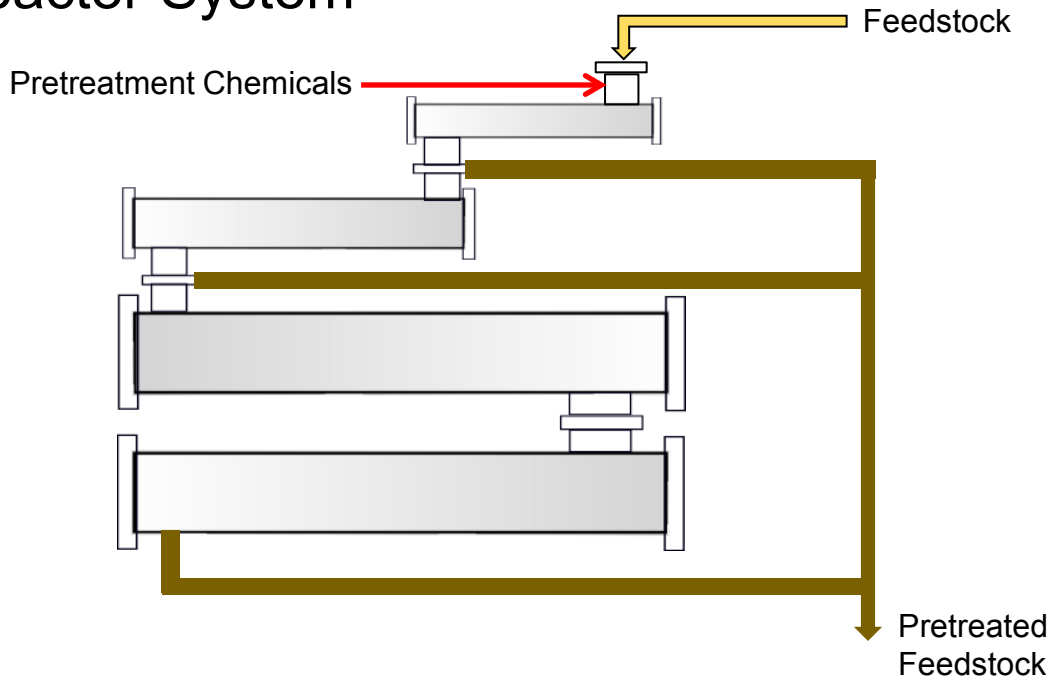
Flad Architects

Pretreatment

Single Horizontal Screw Reactor



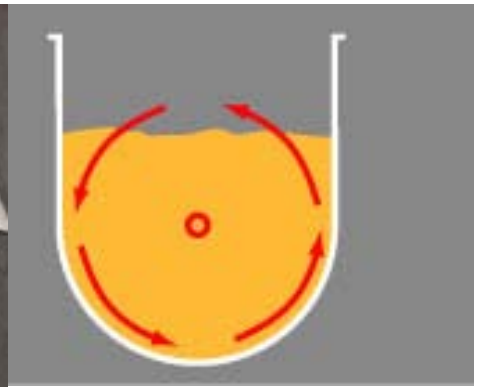
Multi-Tube Reactor System



Versatile Pretreatment System

- Residence times: minutes to 2 h
- Temperatures: 150° to 225°C
- Designed for a variety of pretreatment chemistries

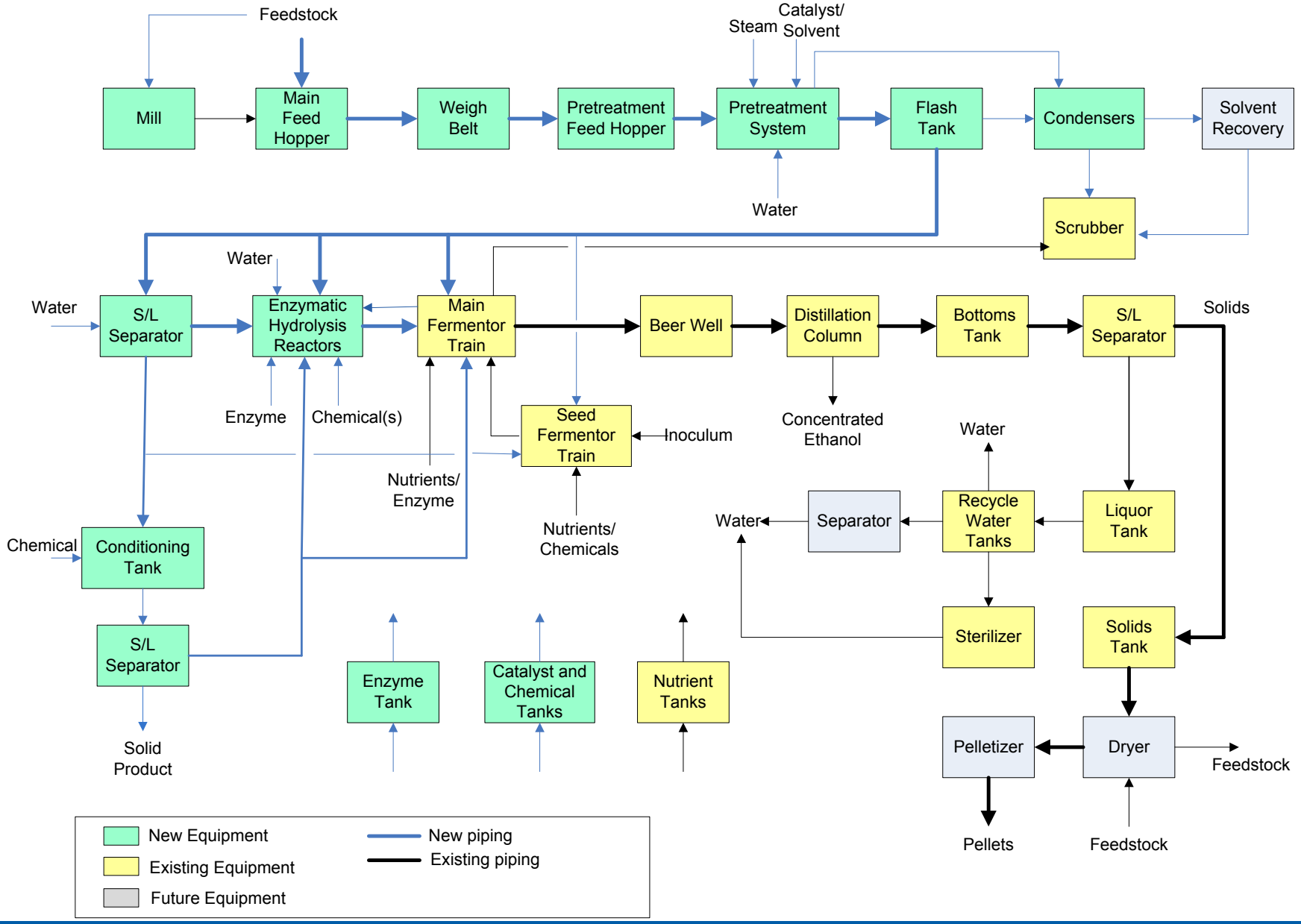
High Solids Enzymatic Hydrolysis



High Solids Enzymatic Hydrolysis Reactor

- Commercially available batch mixer
- No limitations on solids loading
- Thoroughly mixes
- Chemicals and enzyme added via a distributed spray system

Integrated Pilot Scale Processing



Acknowledgements

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Contributors

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  - Dave Sievers
  - Millie Zuccarello
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H+L architecture

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Questions?