

Proving Biochemical Technologies at the Pilot Scale for Integrated Biorefinery Development



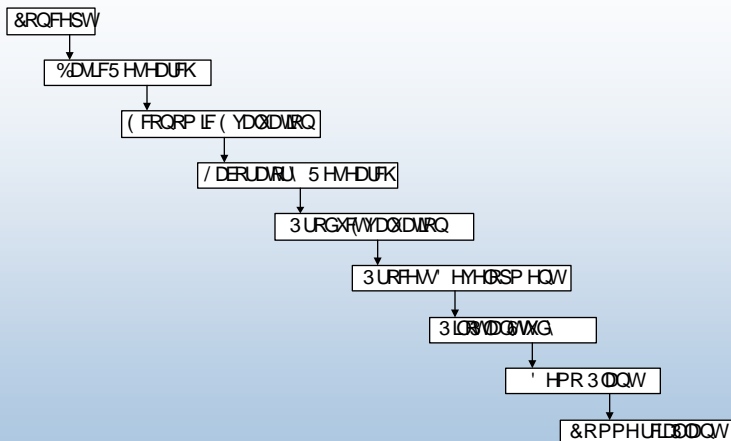
Daniel J. Schell
 National Bioenergy Center
 National Renewable Energy Laboratory
 Golden, Colorado, USA

IEA Bioenergy Executive Committee Meeting
 Golden, CO USA
 April 25, 2007



NREL National Renewable Energy Laboratory

Typical Research Program



Increasing Resource Commitment



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Pilot plants are used to...

- Generate critical information about the behavior of the system for use in design of larger demonstration/commercial facilities
- Reduce the risk associated with design, construction and operation of large process plants



Photos: http://www.pos.ca/facilities/equip_list.php



Reduce risk because they are...

- Less expensive to build and operate
 - Confirm feasibility of proposed process
 - Easier to implement process changes
 - Work out process kinks/bottlenecks
 - Produce product for testing



Photos: http://www.pos.ca/facilities/equip_list.php

- Provide data for design of full-scale plants
 - Chemical reactions
 - Mass and heat balances
 - Material of construction
 - Control strategies
 - Operating costs



What lessons can we learn from the past?



Oil Shale Mining

Experiences from the
synthetic fuels industry
(1970's)

Shale Retort Plant



→ Need to accurately estimate
cost and performance!*

* "Understanding Cost Growth and Performance Shortfalls in Pioneer Process Plants", a study by the Rand Corp. for US DOE (1981)

Photos: <http://ostseis.anl.gov/guide/photos/index.cfm>

The problems are caused by...

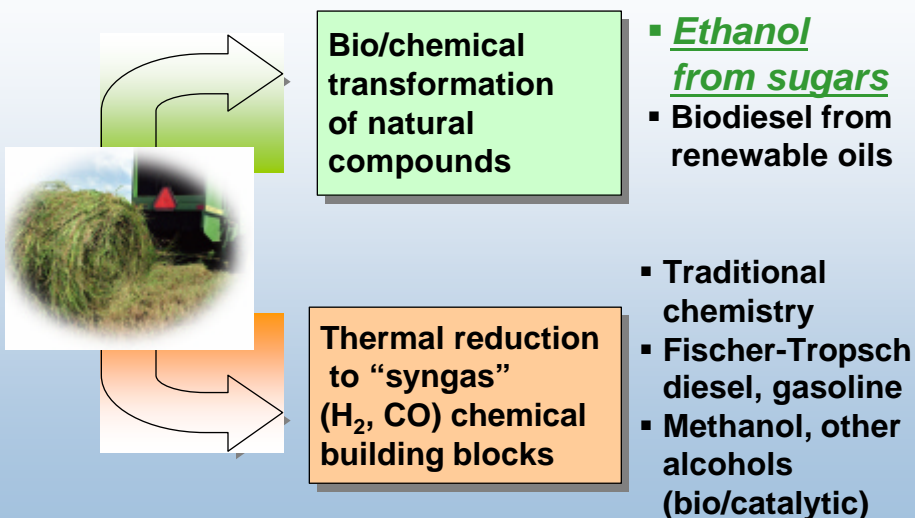
- Growth of plant cost estimates strongly correlated with:
 - Lack of process understanding
 - Stage of development, i.e., project definition
 - Bench to pilot to demonstration
- Plant performance shortfalls strongly correlated with:
 - Number of new unit operations
 - Percent of heat and mass balance equations based on plant data
 - Level of design difficulties encountered with waste handling
 - Plants processing solid feedstocks



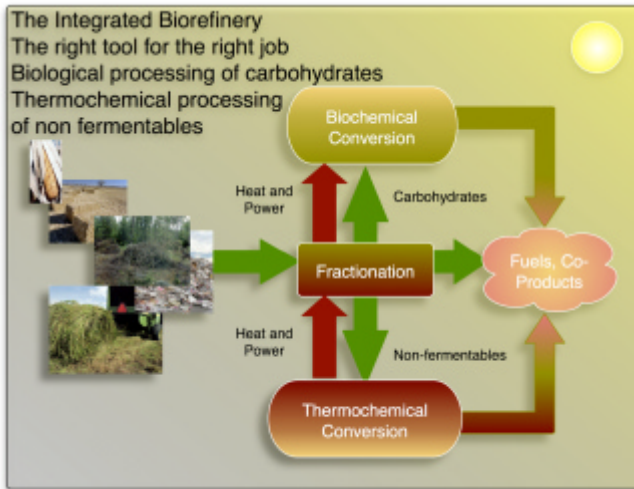
Why is understanding cost and performance important?

- Allocation of R&D dollars
- Capital expenditures
- Facilitates comparisons between competing technology options

Routes to Biofuels



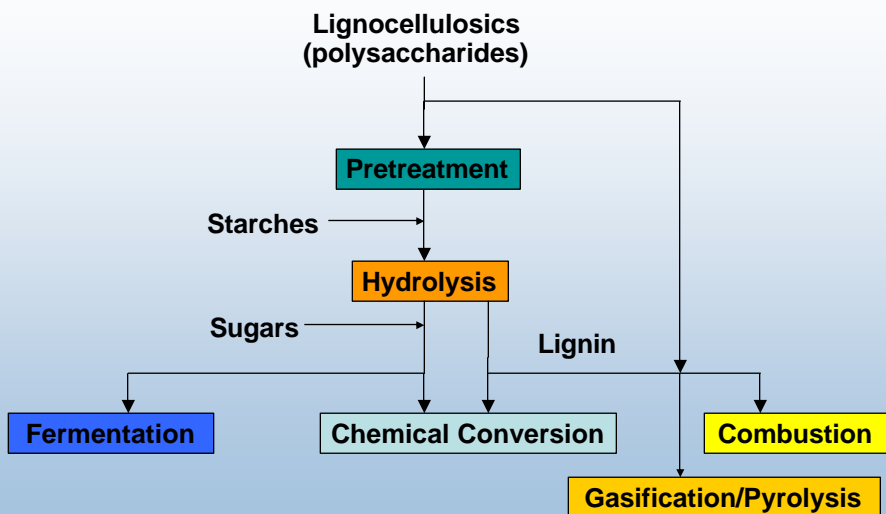
The (Fully) Integrated Biorefinery



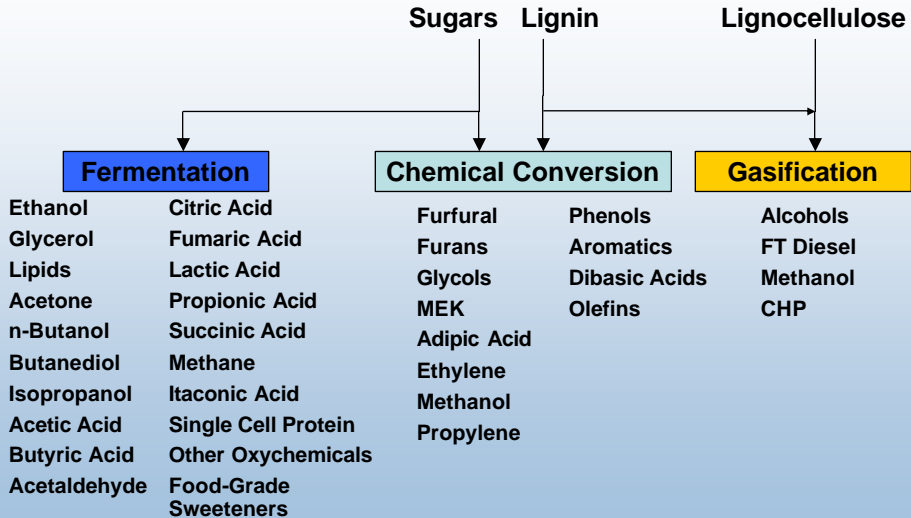
An effective integrated biorefinery *must* include biochemical *and* thermochemical conversion

Maximize efficiency of biomass (and land) utilization by producing fuels thermochemically and biochemically

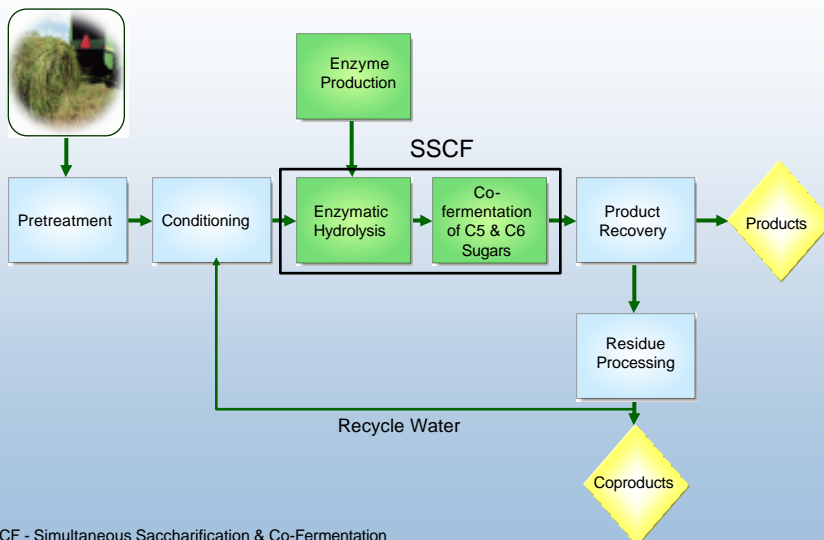
Conversion Routes for Biomass



Many products can be made from Biomass



Biochemical Processing



Piloting Biochemical Processes



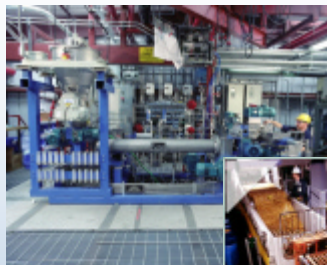
Pretreatment

What are the issues/concerns pilot scale testing can address?

Piloting Biochemical Processes



Pretreatment



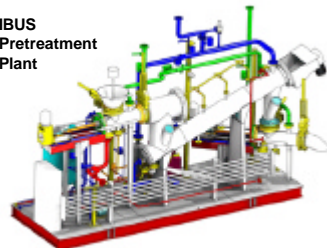
Horizontal
Pretreatment
Reactor



logen Pilot Plant

- Continuous solids processing
- Screening, control and optimization of reaction chemistry (kinetics)
- Power and heating/cooling requirements (heat and mass transfer)
- Corrosion and erosion

IBUS
Pretreatment
Plant



Piloting Biochemical Processes



Pretreatment

Solid-Liquid
Separation/
Conditioning



Hose Pump and Centrifuge



Pressure Belt Filter

- Separation performance and washing efficiency
- Reaction chemistry

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Piloting Biochemical Processes



Pretreatment

Solid-Liquid
Separation/
Conditioning

Enzymatic
Hydrolysis



- Solids loading
- Power and mixing requirements
- Reaction yields

IBUS High Solids Bioreactor



Piloting Biochemical Processes



Pretreatment

Solid-Liquid Separation/ Conditioning

Enzyme Production

Enzymatic Hydrolysis

- Solids loading
- Mixing/power requirements

Co-fermentation of C5 & C6 Sugars



Fermentation Process Train

Piloting Biochemical Processes



Pretreatment

Solid-Liquid Separation/ Conditioning

Enzyme Production

Enzymatic Hydrolysis

Co-fermentation of C5 & C6 Sugars

Product Recovery

Residue Processing

- Residue handling
- Performance of product and residue recovery operations



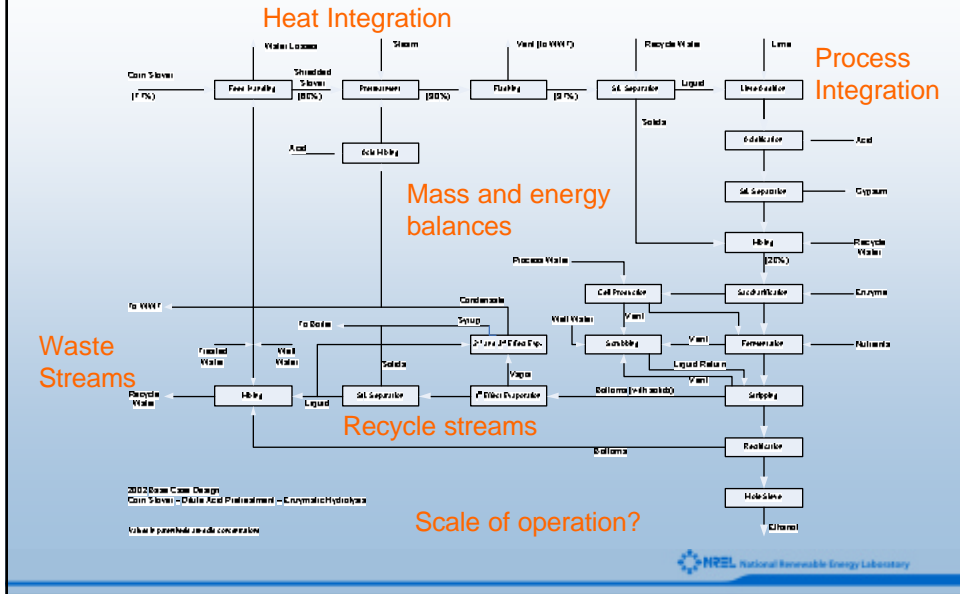
Steam Tube Dryer



Distillation Column

Piloting Biochemical Processes

General Considerations



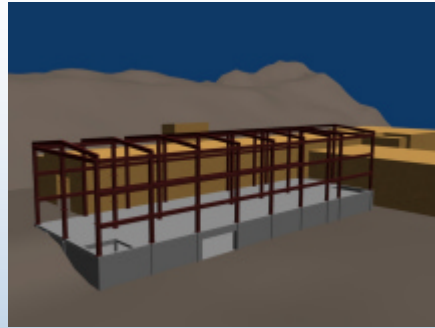
DOE/NREL Biochemical Conversion Pilot Plant

- Processes 1 dry tonne/day
- Integrated unit operations
 - Feedstock handling/feeding, pretreatment, seed culturing, enzymatic hydrolysis and fermentation, distillation, solid-liquid separation
- Operational in 1995
- Used by many industrial clients



DOE/NREL to Expand Its Current Piloting Capabilities

- Motivation
 - Provide additional space to enable testing a wider range of equipment and processing options/configurations
 - Support DOE's accelerated biofuels technology deployment efforts
- Design Considerations
 - Plug and play capability
 - Skid-mounted equipment or unit operations that plug into existing or new process train(s)
 - Flexible access to utilities
 - Horizontal versus vertical (gravity) or stair-stepped flow
 - Containment/isolation
 - Process materials
 - Volatile solvents/catalysts



New capabilities will enhance the value of the facility to industry

- Multiple front-end process trains able to handle a wider range of pretreatment chemistries
- Additional unit operations
 - Separation/product recovery (e.g., membranes)
 - Lignin-rich residue handling/processing (e.g., drying)
- Expanded instrument and control capabilities
 - Feedback control using on-line instruments

Acknowledgments



- Funding
 - USDOE's EERE's Office of the Biomass Program
- Equipment and process photos from various internet sites (as cited)

More Information

- The National Renewable Energy Laboratory:
<http://www.nrel.gov>
- DOE's Biomass Program:
<http://www.eere.energy.gov/biomass/>
- DOE-USDA Biomass R&D Initiative:
www.bdrisolutions.com
- Alternative Fuels:
<http://www.afdc.doe.gov>