

# **A Wood-to-Wheels Graduate Enterprise: *Bioprocessing Initiatives***

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# Bio-Processing

- **MTU Faculty Collaborators**

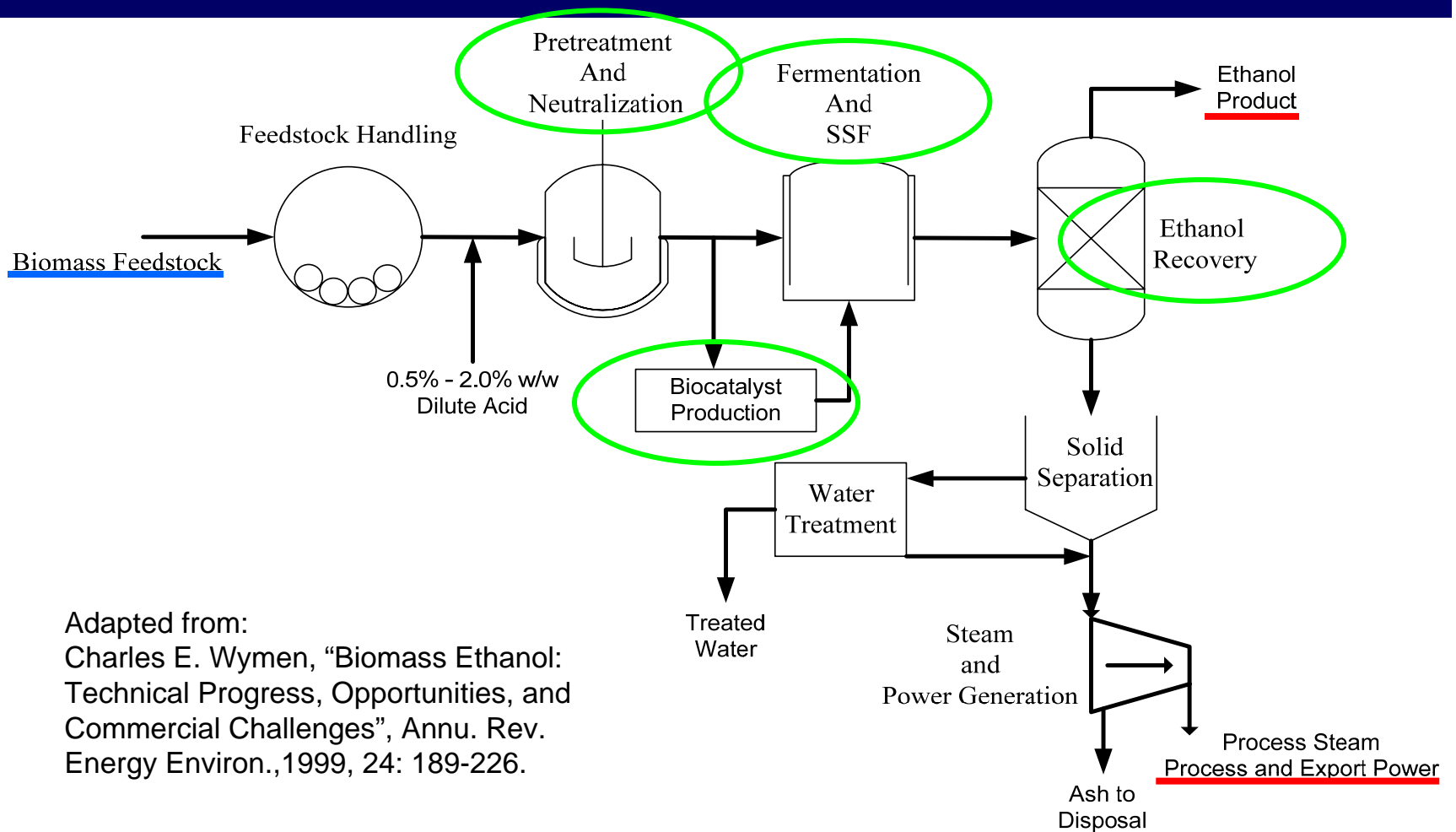
- David Shonnard, Professor, Chem. Eng.
- Susan Bagley, Professor, Bio. Sci.
- Heather Youngs, Asst. Professor, Bio. Sci.
- Patricia Heiden, Assoc. Professor, Chemistry

- **External Collaborators**

- American Forest and Paper Assoc.
- National Bioenergy Center, NREL
- American Process, Inc.
- SUBR/Center for Energy and Environmental Studies
- General Motors Corporation

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# Example Process to Convert Lignocellulosic Biomass to Ethanol (NREL)



# Bioprocessing Initiatives:

## *Thermochemical Conversions*

- **Optimize** biomass-to-sugar reactions
- Reduce byproduct reactions
- Evaluate timber species mixtures
- **Materials compatibility** issues

## *Integrated Bioprocess Facility*

- **Integrate** fermentation and purification to increase fuel yields
- **Test** monitoring devices and process control schemes
- **Minimize** energy consumption and waste generation

## *Biochemical Conversions*

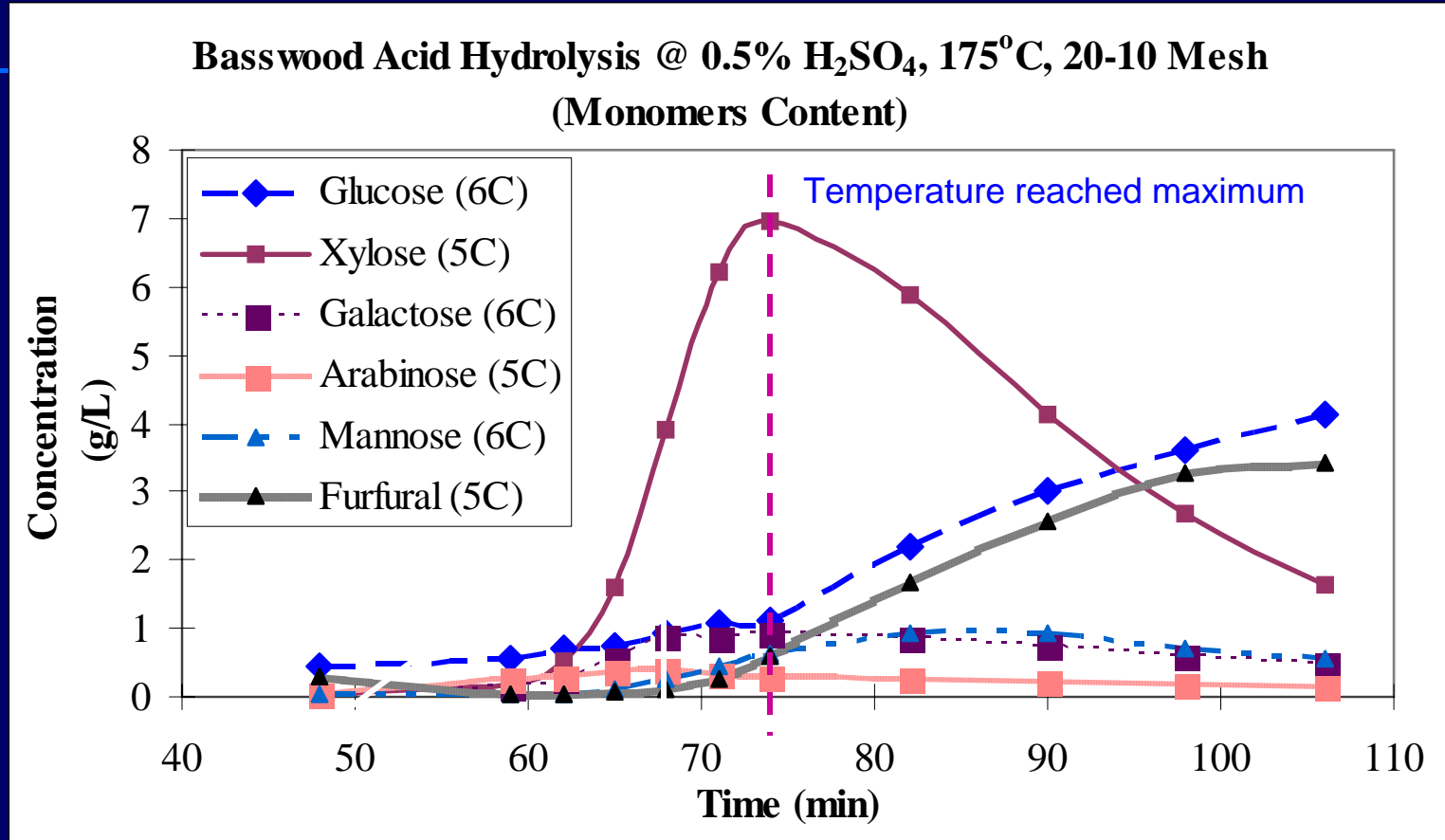
- Develop/test high-activity **cellulases** for tree species mixtures
- Generate more easily metabolized sugars using **epimerases**
- Improve fermentations for **high yields** of ethanol / other bio-based materials
- Use metabolic flux analysis to guide **strain improvement**

## *Product Purification*

- **Boost** yields by coupling membrane separation with fermentation
- **Conserve** water by recovering and recycling fermentation nutrients

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# Pretreatment Results: *Sugar/Byproduct Concentration Profile*



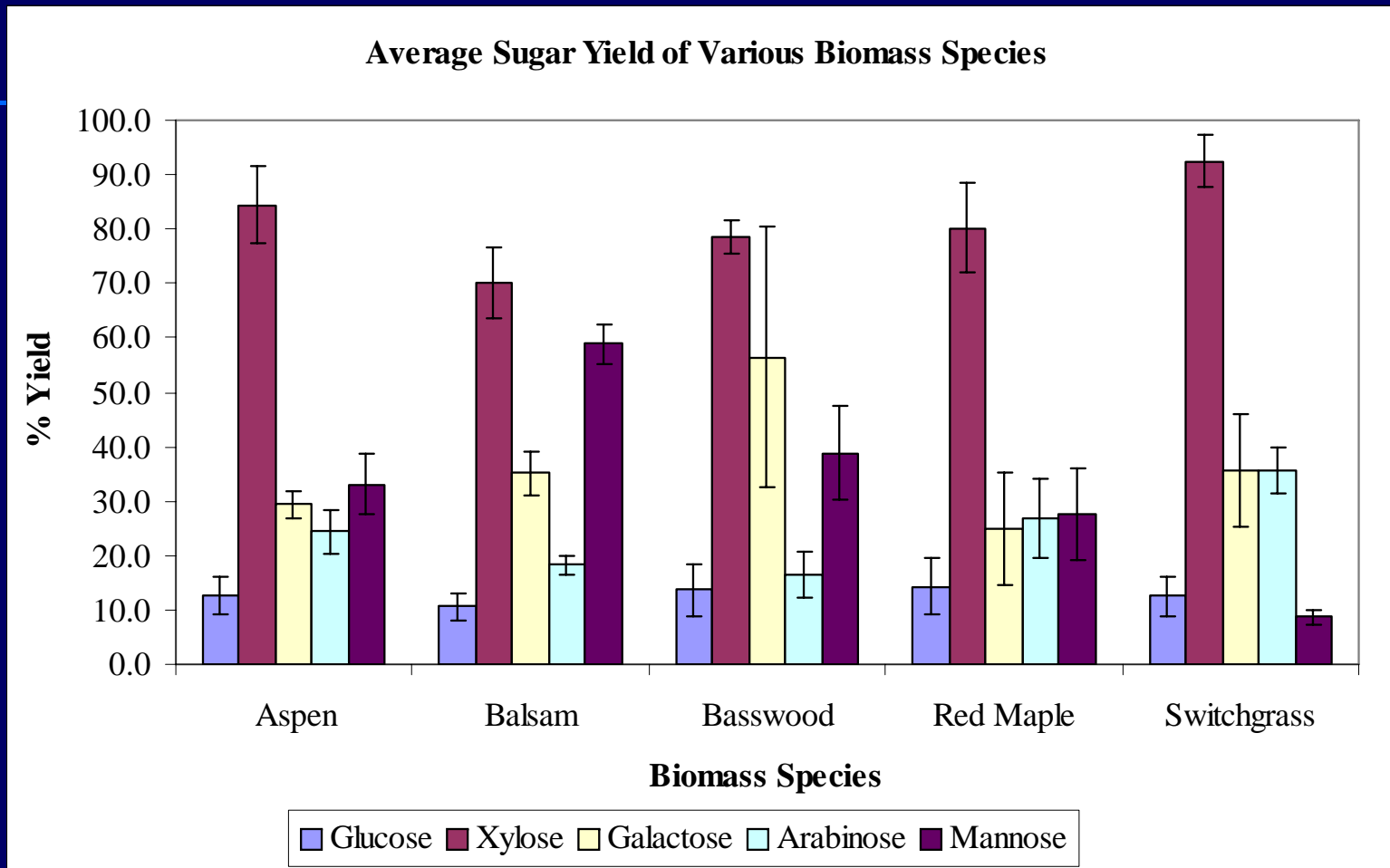
Most hemicellulose was hydrolyzed to sugars

Xylose Concentration increased rapidly

Minor sugars degraded to their by-product

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# Pretreatment Results: *Overall Yield*



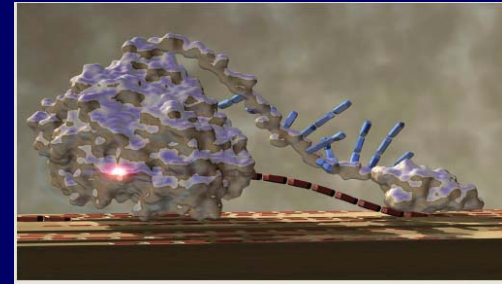
Higher xylose concentration  
on Aspen & Switchgrass

Higher mannose concentration  
on softwood

# Future Research

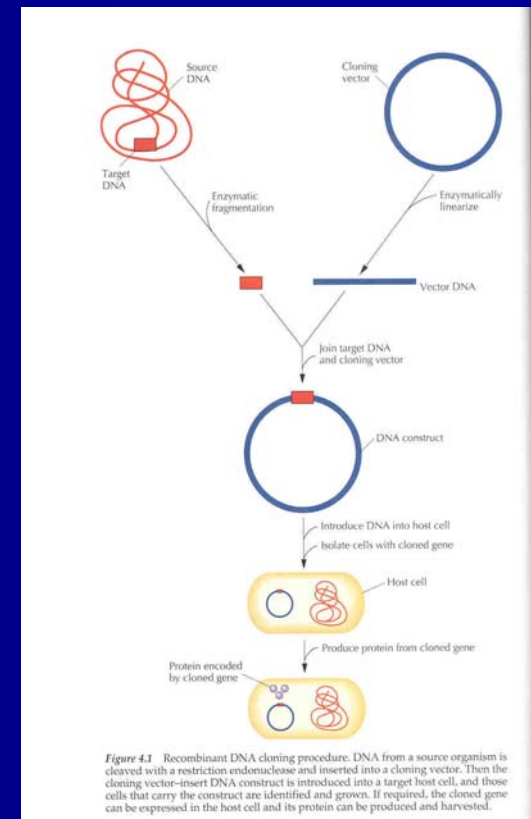
- Investigate mixtures of different tree species for maximum xylose yield
- Reactor issues,
  - Materials compatibility and cost
  - Larger reactors will improve experiment accuracy
- Use of process modeling to optimize conversions
  - Reactor types
  - Control of temperature and residence time

# Enzymatic Reactions

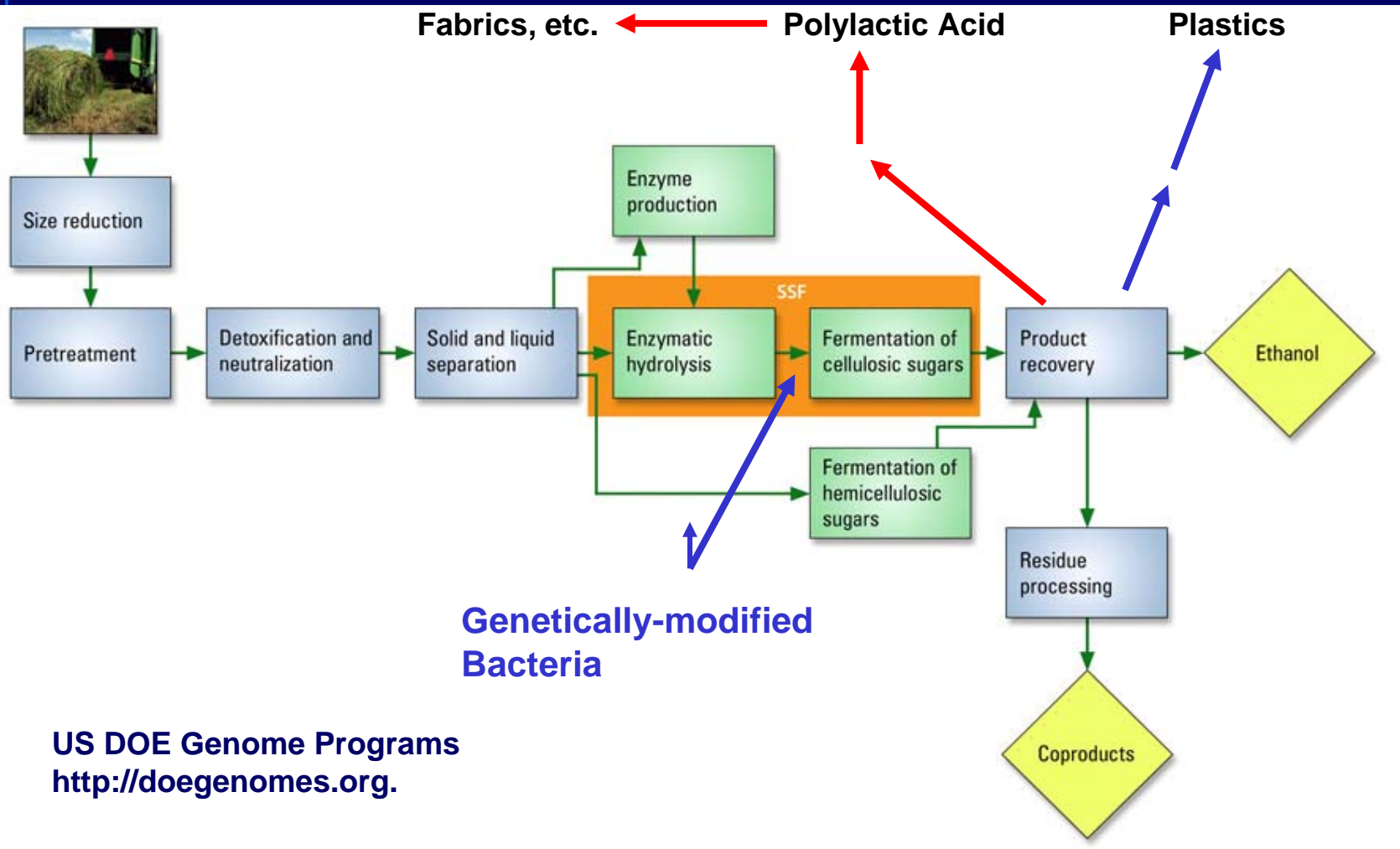


Cellulase image from M. Himmel et al., "Cellulase Animation," run time 11 min., National Renewable Energy Laboratory (2000).

- Cellulases are fungal enzymes that break down cellulose to glucose
- Epimerases interconvert sugars
- Improving cellulase activity
  - Recombinant DNA approach
- Modify cellulase binding
  - Cellulose surface
  - Lignin surface to minimize enzyme use

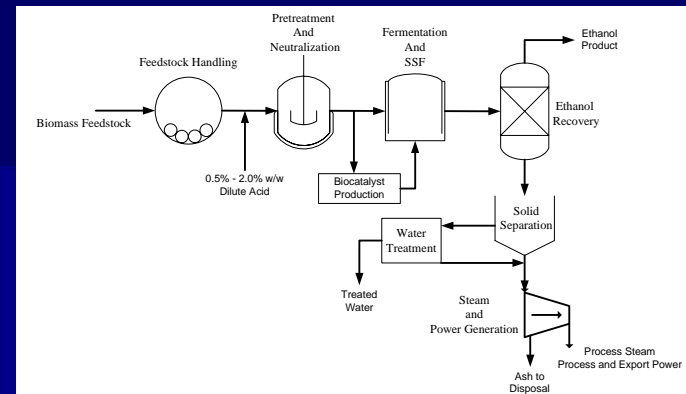


# Fermentation: *Microbial Improvement / Coproducts*



US DOE Genome Programs  
<http://doegenomes.org>.

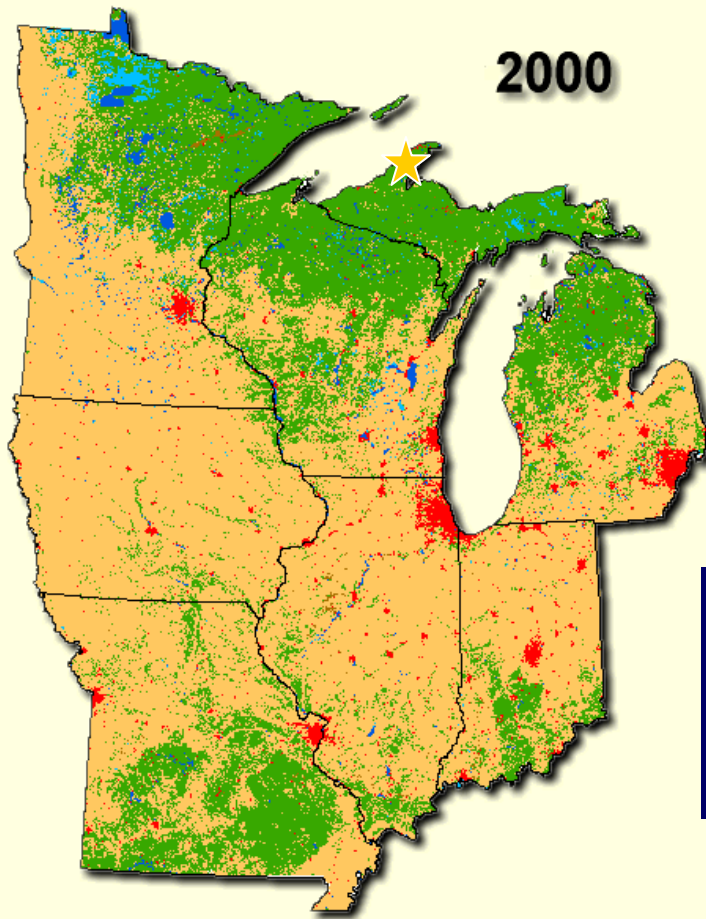
# Research Pilot Plant Vision: *Biorefinery in Miniature*



- 100 gallon ethanol / day
- Incorporate research innovations
- Test bed for process design / evaluation data
  - Measure mass - energy balances / process control
  - Cost / environmental impact / energy efficiency analyses
- Undergraduate experiences
  - Research associates / process improvement teams

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# Questions?



Midwestern land cover (USFS North Central Research Station image)

