

# Fermentation of Biomass to Ethanol:

## Adding Value Prior to Pulping

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# Outline

- Background
- Woody biomass fermentation
- Adding Value Prior to Pulping (VPP)
- VPP Consortium
- Fermentation microorganisms
- Experimental design
  - Microbe strain development
  - Inhibitor assay
- Opportunities and Future Plans

# The Opportunity and Potential

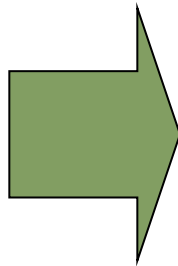


PULP WOOD



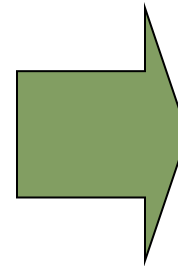
## Forest Biomass Feedstock

- Forest residues
- Hazardous fuel treatments
- Short rotation woody crops
- Wood waste



## Conversion Processes

- Manufacturing
- Co-firing
- Combustion
- Gasification
- **Enzymatic fermentation**
- **Gas/liquid fermentation**
- **Acid hydrolysis/fermentation**



## USES

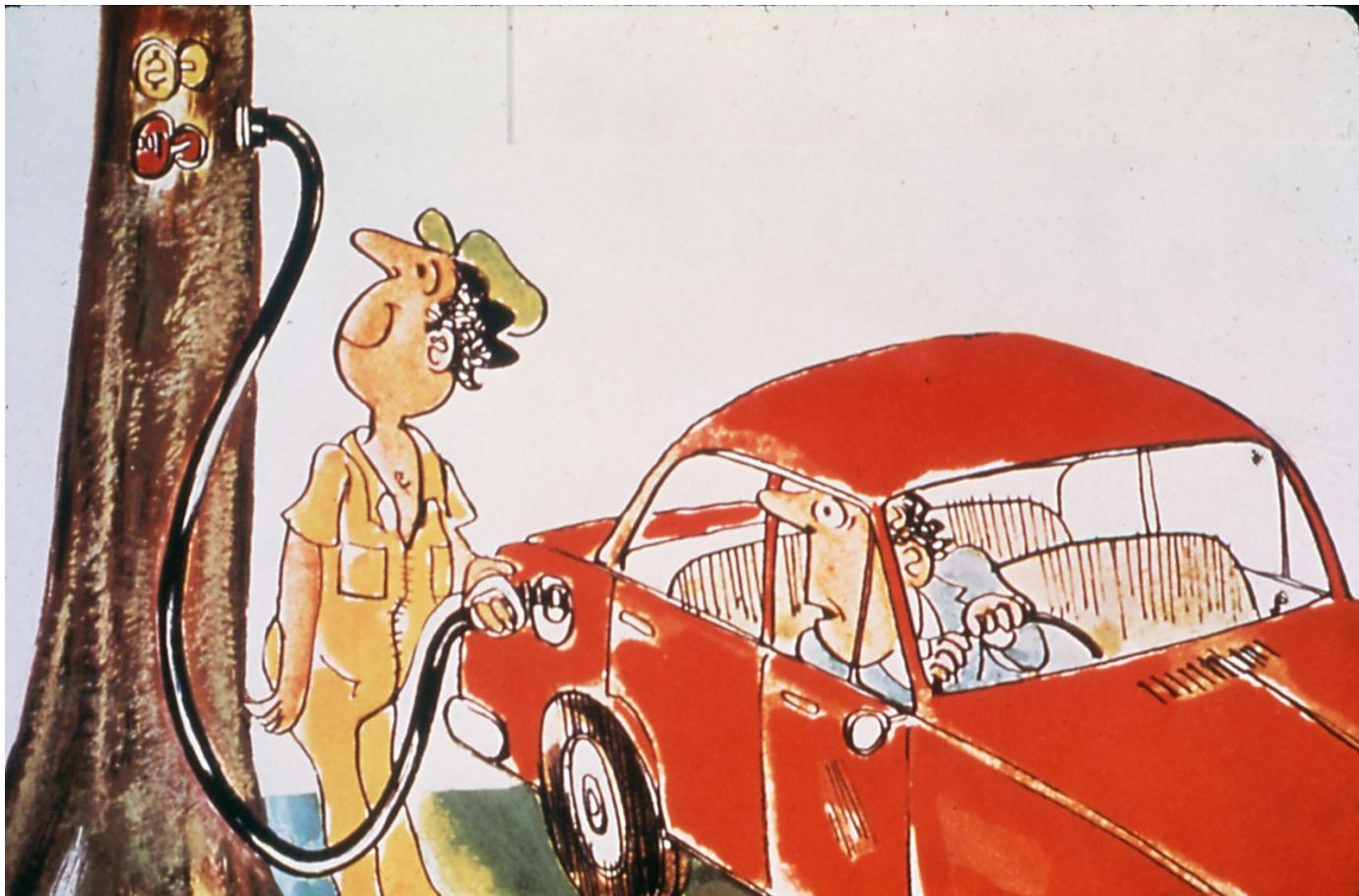
- Renewable diesel
- **Ethanol**

### Electricity and Heat

### Biobased Products

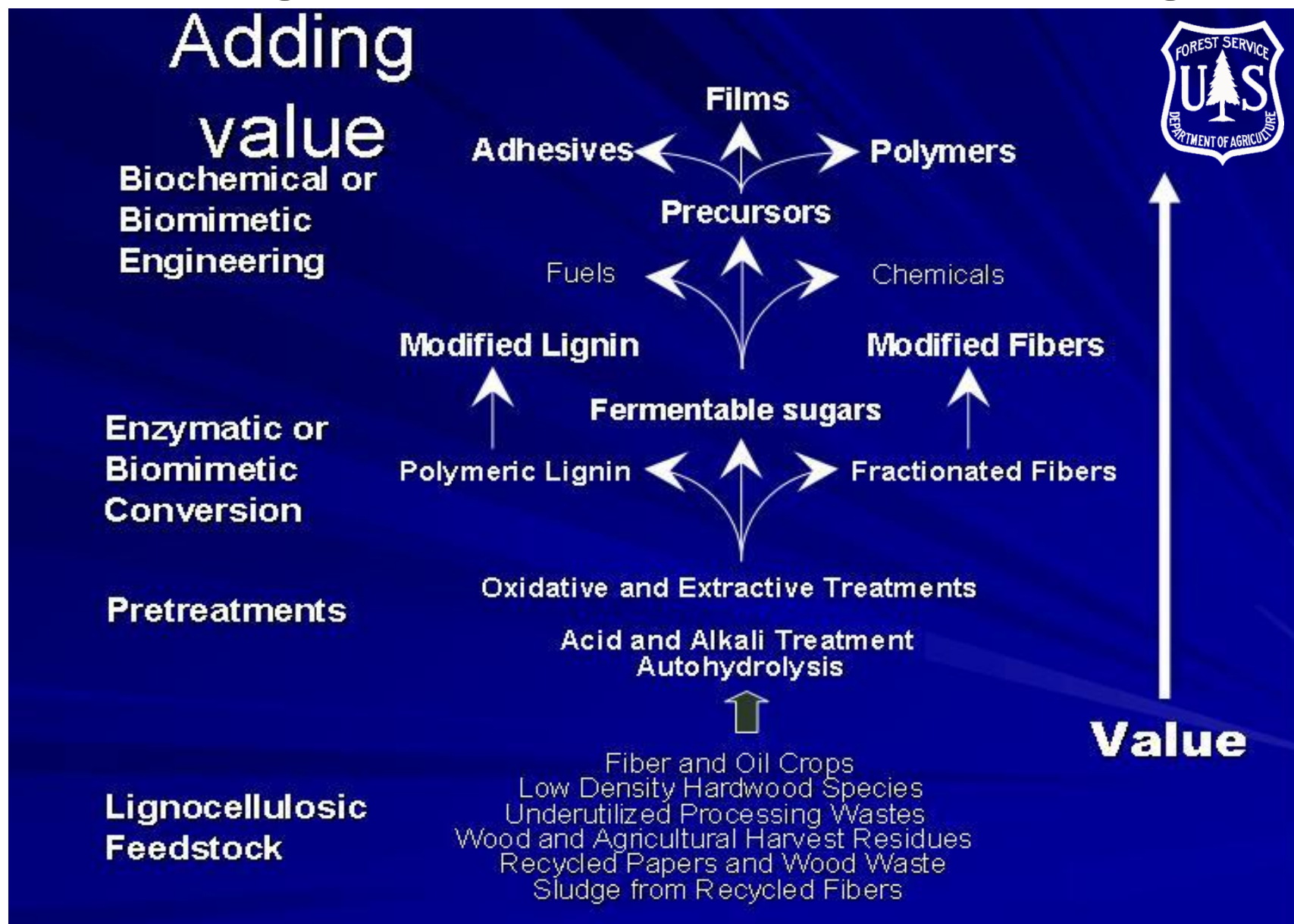
- Composites
- Specialty products
- New products
- Chemicals
- Traditional products

# Biofuels (*& Chemical Feedstock*) from Woody Biomass





# Adding Value Prior to Pulping



# Value Prior to Pulping (VPP) Consortium

- Organized and approved by AF&PA  
(American Forest and Paper Association's)  
Agenda 2020 Technology Alliance

[www.agenda2020.org](http://www.agenda2020.org)





# VPP Consortium Members

- \*US Forest Service, Forest Products Lab
- \*Eight pulp and paper companies
- \*Enzyme companies
- \*Five Universities
- \*A non-profit economic development group
- \*DOE National Renewable Energy Lab

# VPP Consortium Teams

\*Pulping

\*Extract Processing

\*Fermentation & Ethanol Production

\*Modeling-Economic Assessment



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# Fermentation & Ethanol Production Team

- Forest Products Lab
- Purdue
- NREL
- SUNY
- Catchlight Energy



# Fermentation and Ethanol Production Team (FEPT)

- Microorganisms; enzymes
- Work with pulping & extract processing teams
- Provide final data to modeling team for business case evaluation



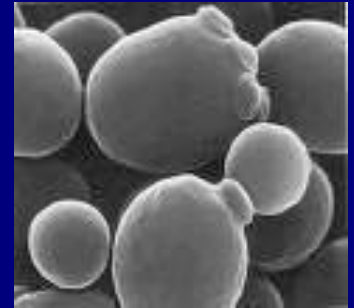
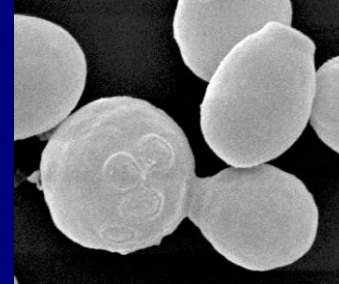
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# Fermentation Microorganisms

## Yeast

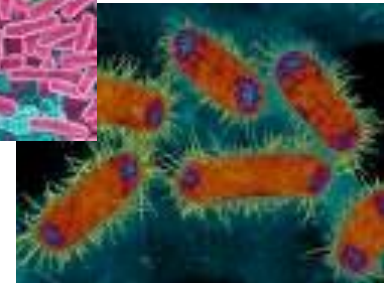
*Pichia stipitis*

*Saccharomyces cerevisiae*



## Bacteria

*Zymomonas mobilis*



# Microbial Strain Improvement

## Desired Characteristics

- hydrolyzate tolerance
- ethanol tolerance
- pH stability
- high fermentation rate
- improved xylose fermentation

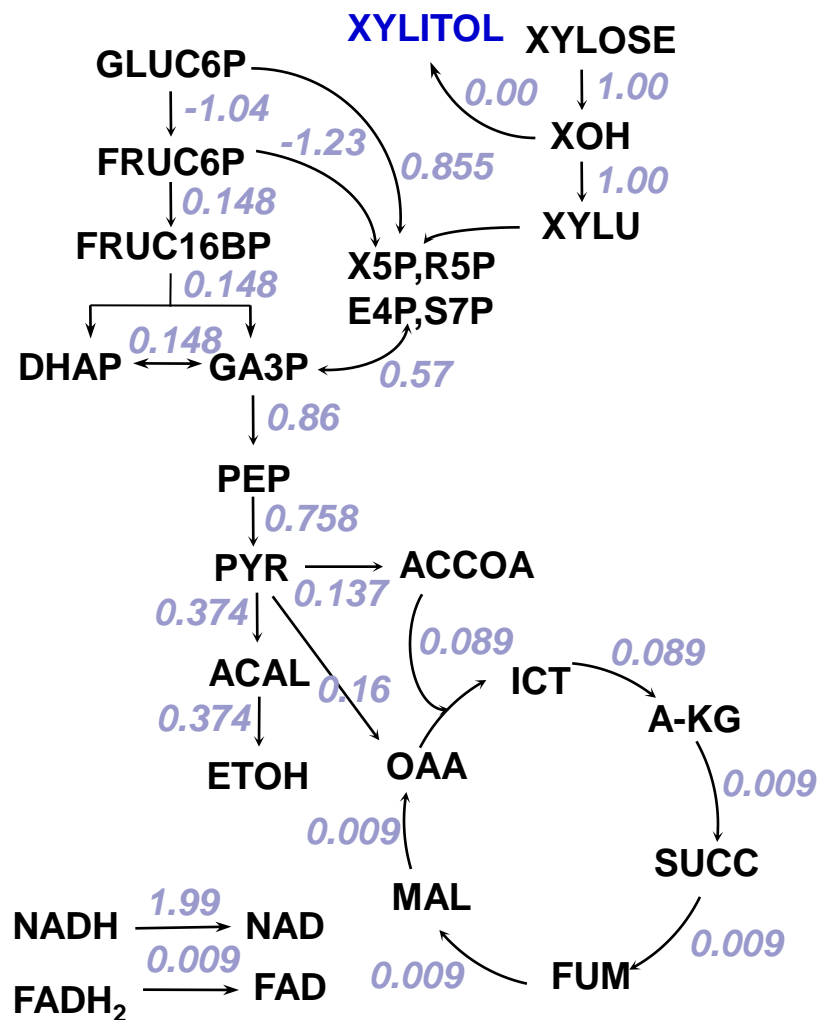
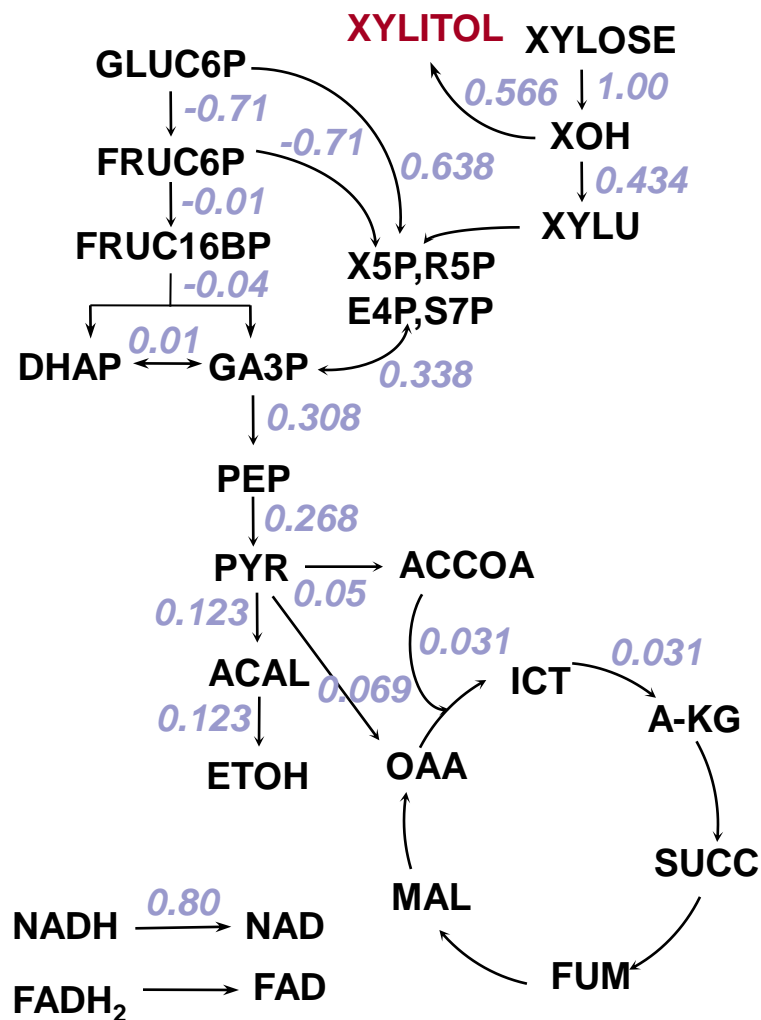


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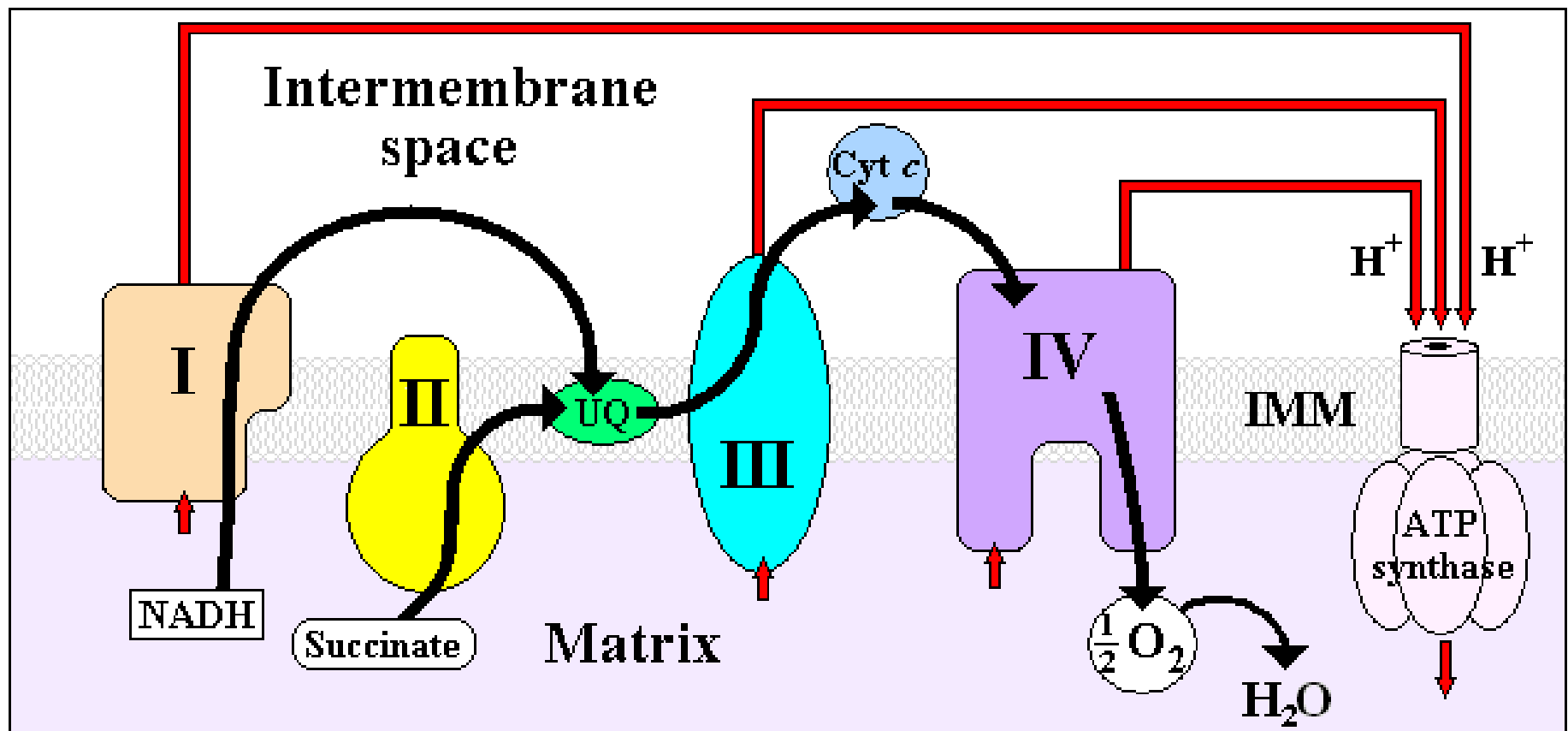
## Xylitol is dominant product

### Phase 2 (1.0 mol O<sub>2</sub>/mol xylose)

## Ethanol and biomass are dominant

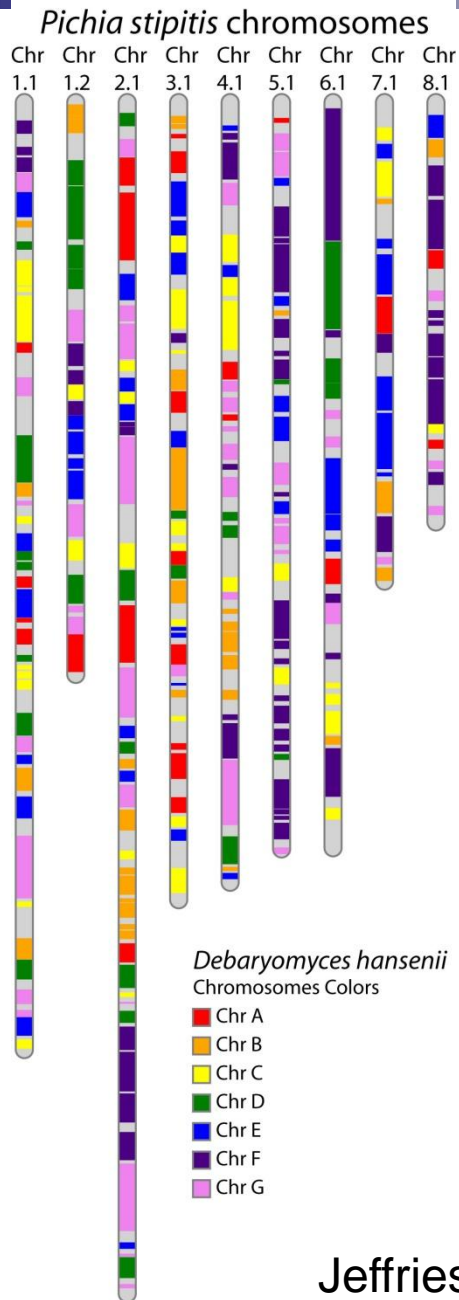


# Directing Fermentation Toward Ethanol Production



Energy Production in Mitochondria





## Complete Genome

The *P. stipitis* genome  
has a remarkable  
level of functional  
organization

## Increase

### Fermentation rate

Basic strategy avoids  
*transgenic* modification

Use *P. stipitis* genes  
in *P. stipitis*

**Ethanol tolerance improved**

Jeffries et al.



# Microbial Growth Inhibitors

Inhibitors can affect

- Growth
- Development
- Specific enzyme function
- Low ethanol production

# Microbial Growth Inhibitors

## Inhibitors can affect

- Growth
- Development
- Specific enzyme function
- Low ethanol production

- Many unknown
- Known inhibitors
  - Acetic acid
  - Furfural



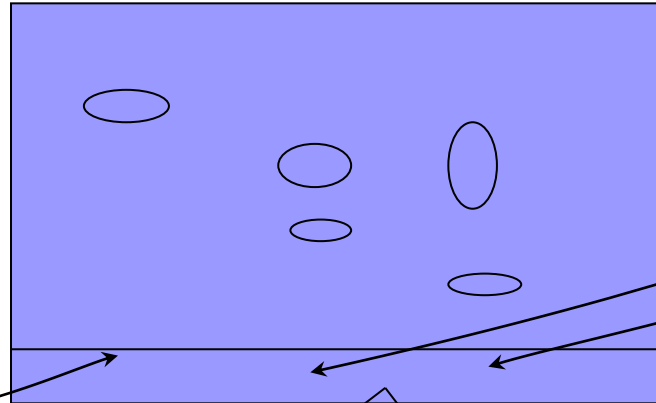
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# Inhibitor Assay

1. Prepare and plate VPP Hydrolysate

2. Plate commercial standard (e.g. Furfurol)

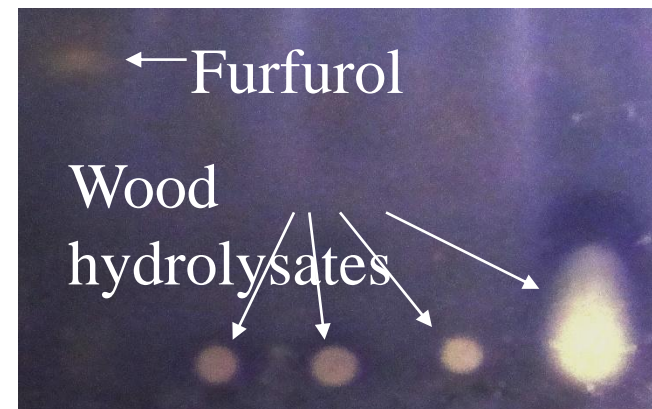


3. Develop plate

4. Overlay plate with organism of interest (e.g. *Saccharomyces*), incubate.

5. Measure inhibition with vital dye staining

IEA poster

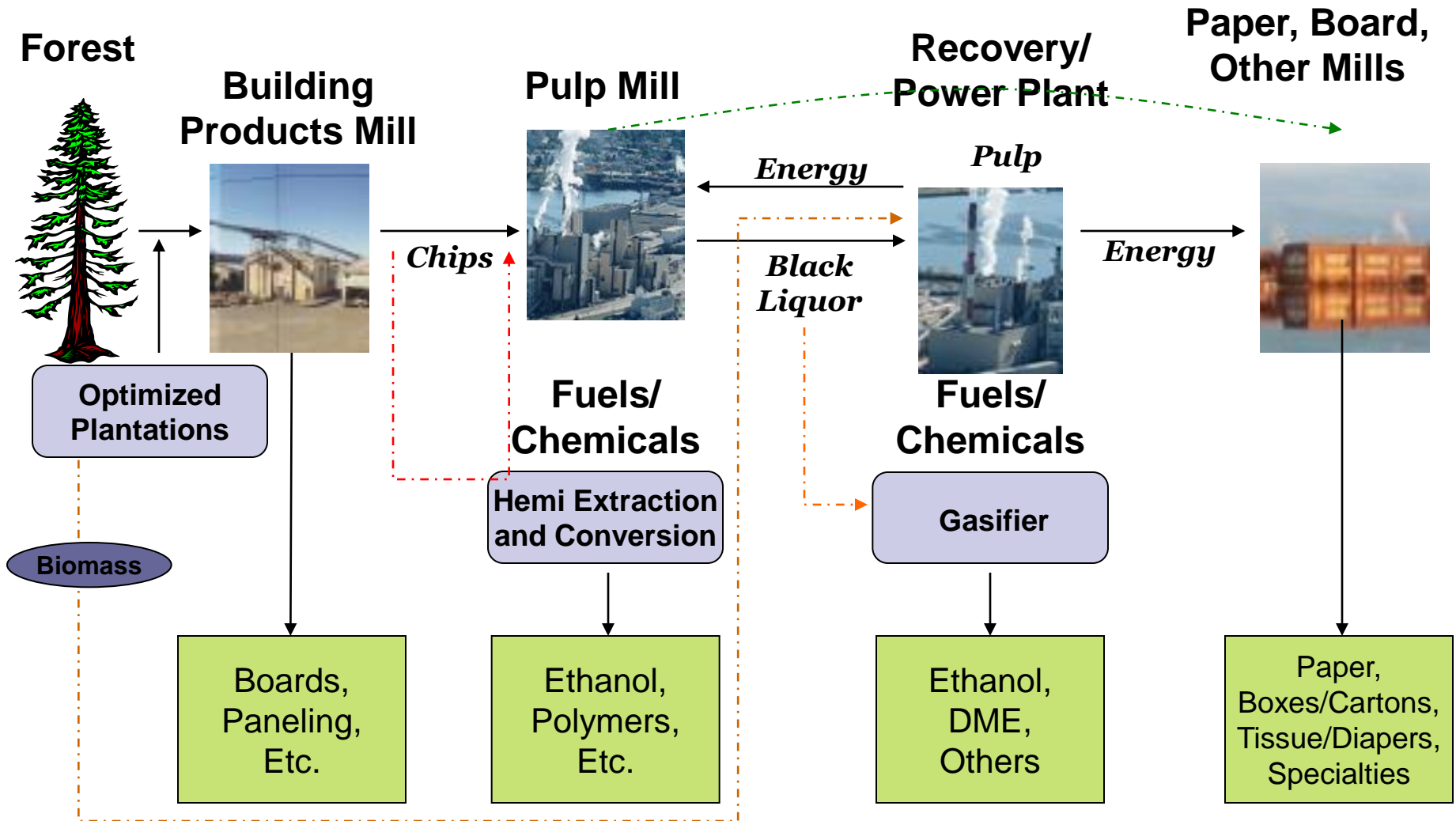


# VPP Fermentation Technical Challenges

- Economy of scale equivalent to world class pulp mill (6000 dry tons per day)
- Achieving ~95 gallons of EtOH per dry ton
- Fermentation of C-5 sugars and mixed streams of C-5/C-6 sugars
- Ethanol tolerance
- Aerobic vs. Anaerobic

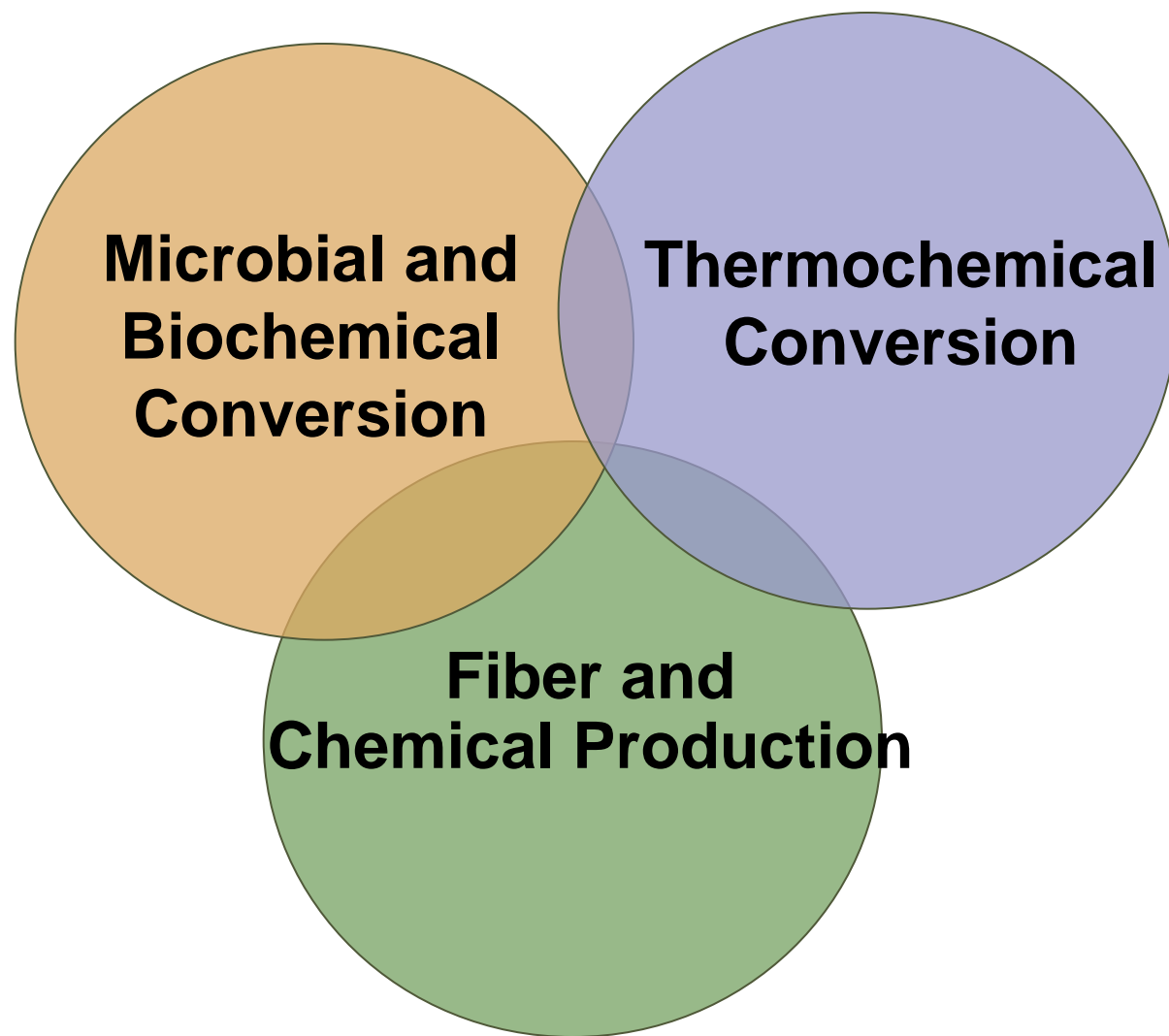


# Integrated Forest Products Biorefinery





# FPL Biorefinery Pilot Plant



- **USDA ARS**
- **Industry**
- **Academia**

# Forest Products Lab Pilot Plant





# Forest Products Lab



# Thank you!



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## Q&A



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*1910–2010*