Forest Products Industry
Pulp/Paper Innovation

- Conventional
- Evolutionary
  - Biobased Chemicals
  - Materials
  - Fuels
- Revolutionary
Forest BioResources Focus

What will the BioResources for the Forest BioRefinery of the Future be?

- Forest
- Plantations
- Urban Lignocellulosics Waste Streams
- Select Ag-Resources
Better Physical/Thermal Properties Using Less Material

Research Opportunities

- AFM of Cellulose Nanowiskers
- Birefringence of Cellulose Nanowiskers
- TEM of Cellulose Nanowiskers

Crosslinked

Xylan Films

Water Vapour Transmission/h

O₂ & strength

% Sulfonated Whiskers

0 100 200 300 400
0% 5 10

Plastics

AFM of Cellulose Nanowiskers

Birefringence of Cellulose Nanowiskers

TEM of Cellulose Nanowiskers

Research Opportunities

- Better Physical/Thermal Properties Using Less Material
- Using Less Material

Advanced Bio-Based Research GT
Research Opportunities

Cellulose whiskers - microfibrillated Cellulose
- Improved scalable manufacturing
  - Reactor design, additives, feedstock
- Crosslinked & functionalized nanocellulosics
  - PU, Hemicellulose films/foams/Gels
  - Fundamental Chemistry – Material Science
- Templating
- Hydrophobic polymer composites

Gelatin cross linked with nanowhiskers
Biorefining: Fibers

Emerging markets for pulp fiber reinforced concrete cast-in-place and precast sections

Research Need: Develop fibers with good dispersion, stability and improved performance

In-situ synthesis of iron oxide nanoparticles within cellulose media yielding stable suspensions

Research Needs:
- Fundamentals of plastic-fiber-inorganic compatibility
- Extrusion engineering
- New bio-polymers
- Advanced biocomposites
BioRefining: BioFuels

Biological Biorefinery Biofuel Grand Challenges:
1. Pretreatment most costly stage
2. Lignin/Hemicellulose/Cellulose Separations
   - Biotreatments
   - Autohydrolysis, AFEX, Organosolv
   - Additives assisted
   - Ionic & supercritical liquids

Recalcitrance Fundamentals
- Native/transgenics
- Deconstruction
- Conversion
Biofuels Background

Cellulosic biofuel projects with plans to begin producing by 2015

Feedstock Cost @ $4 to $8/bu = $11 to $22/GJ
= $63 to $126/bbl oil

Capital Cost $2/annual gallon

Currently ~$10/annual gallon.
However, similar flow sheets for advanced cellulosic biomass and corn suggest potential for similar capital costs.

Definition of Acceleration
Science: Rate of change of the velocity of a moving body
Business: The shortening of the time
The BioEnergy Science Center

A multi-institutional, DOE-funded center performing basic and applied science dedicated to improving yields of biofuels from cellulosic biomass

300+ People in 17 Institutions

Oak Ridge National Laboratory
National Renewable Energy Laboratory
Samuel Roberts Noble Foundation
ArborGen, LLD
Ceres, Incorporated
Mascoma Corporation
DuPont
GreenWood Resources

University of Georgia
University of Tennessee
Cornell University
Dartmouth College
West Virginia University
Georgia Institute of Technology
University of California–Riverside
North Carolina State University
University of California—Los Angeles
To enable the emergence of a sustainable cellulosic biofuels industry by leading advances in science and science-based innovation resulting in removal of recalcitrance as an economic barrier to cost-effective production of biofuels.
Access to the sugars in lignocellulosic biomass is the current critical barrier

• Overcoming this barrier will cut processing costs significantly and be used in most conversion processes

• This requires an integrated, multi-disciplinary approach

• **BESC believes biotechnology-intensive solutions offer greatest potential**
Biorefining: BioFuels/Materials

Chemicals

Biological Biorefinery Biofuel Grand Challenges:

4. Lignin
   • Power /Chemicals/Materials
   • BioFuels: Green Gasoline-Diesel

Lignin $\sim C_{800} - C_{900}$ → $C_8 - C_{22}$

Fragmentation

Research Needs
Next Generation Catalyst
Biorefining: BioFuels

Catalytic Pyrolysis
Lignin – Bark
Forest Residues

Pyrolysis
- Next Generation of Additive(s)
- Dehydration/decaboyxylolation
- Decarbonylation
- Recyclability
- Reactor design/scale-up

Upgrading
- Nobel catalyst(s)
- Integration to petroleum refining
Biorefining: BioFuels - Biopower

Wood Pellets
Torrefaction

BioPolymers

Biological Platform
Residues

Combined Heat & Power
Clean Gas

Thermochemical Platform
Conditioned Gas

BioFuels Chemicals
Sugar Feedstocks, Lignin Intermediates

Systems Integration = Biorefineries

Research Needs
Catalyst
Reduced Capital
By-Products
GT: Academic’s in Biorefining

Academic Program Accomplishments:
• Multidisciplinary and directed at solving important technical and societal problems relevant to the forest products/biorefinery industry
• Graduate MS/PhD PSE program in four schools:
  • ChBE, MSE, ME & Chem/Biochem
  • Numerous student/teaching awards

Academic Program:
Identify, nurture, guide, challenge best students to be the best - USA/International in Forest Biorefinery
Support new faculty from diverse backgrounds with an interest in Forest Biorefinery

• International Exchanges
• Excellent career opportunities
“The tipping point is that magic moment when an idea, trend, or social behavior crosses a threshold, tips, and spreads like wildfire"

by Malcolm Gladwell