Biorefineries

Opportunities for Industry

Forest
368 million t/yr

Ag Residues
998 million t/yr

Extraction and Bio-conversion

Fiber Production

Energy Conversion

Thermo-Chemical Conversion

Natural Fibers
Polymer precursors

Ethanol, Green
Diesel/Gasoline
High-value chemicals

Power

H₂, Fuels,
Chemicals
Biorefinery Studies

- Biorefinery Products
- Enabling Technologies
- Biomass Characterization
- Biomass Separation
Biorefinery Products

Fiber

Products from wood prior to pulping

- Ethanol from hemicellulose
- Higher value materials from hemicellulose
- Pharmaceuticals and neutraceuticals from wood

Syngas-derived products

- Power
- Hydrogen
- Alcohols
- Ethanol - Butanol from bioconversion
- Methanol & DME
- F-T Liquids

Building block chemicals from wood

- From cellulose
- From hemicellulose
- From lignin
Enabling Technologies for Biorefineries

- **Extraction**: Pharmaceuticals, flavorings and food additives, etc.
- **Bioconversion**: ethanol, organic chemicals, precursors for plastics, etc.
- **Chemical conversion**: fibers, nanomaterials, adhesives, etc.
- **Thermochemical conversion**: fuels, chemicals via methanol route
Enabling Technologies

Extraction of Hemicellulose

- More selective extraction
- Higher concentration in extract
- Recovery of acetate

Conversion Technology: Hemicellulose to Higher Value Materials

- Nanomaterials
- Hydrogels
- Films, Foams
Enabling Technologies

Biochemical Conversion for Building Block Chemicals from Wood

Biomass Feedstocks
- Starch
- Hemicellulose
- Cellulose
- Lignin
- Oil
- Protein

Intermediate Platforms
- Biobased Syngas

Building Blocks
- H₂
- Methanol
- DME
- Alcohols
- F-T Liquids
- C3 Building Blocks (glycerol, lactic acid)
- C4 Building Blocks (succinic acid, acetoin)
- C5 Building Blocks (furfural, levulinic Acid)
- C6 Building Blocks (lysine, sorbitol)
- Aromatic Building Blocks (gallic acid, ferulic acid)
- Direct to polymers and gums

Secondary Chemicals

Intermediates

End Use
Select Biorefinery Chemicals

Building block chemicals
These are molecules with multiple functional groups that can be transformed into high-value bio-based chemicals or materials.

Building block chemicals that can be produced from sugars via biological or chemical conversions:
- 1,4 succinic, fumaric and malic acids
- 2,5 furan dicarboxylic acid
- 3 hydroxy propionic acid
- aspartic acid
- glucaric acid
- glutamic acid
- itaconic acid
- levulinic acid
- 3-hydroxybutyrolactone
- glycerol
- sorbitol
- xylitol/arabinitol
Wood Available to Biorefineries

- U.S. forestlands can produce **368 million dry tons** annually. This includes:
  - 145 million: residues from wood, pulp, paper mills
  - 52 million: fuel wood harvested from forests
  - 47 million: urban wood residues
  - 64 million: residues from logging and site clearing operations
  - 60 million: biomass from forests to reduce fire hazards.

- All of these forest resources are sustainably available on an annual basis.

Source: Perlack et al., 2005.
Product Options

- **Pharmaceuticals:** taxol
- **Food additives:** β-sitosterol, a cholesterol suppressant
- Plastics
- Nanocellulose
- Carbon fibers
- Adhesives
- Chemicals