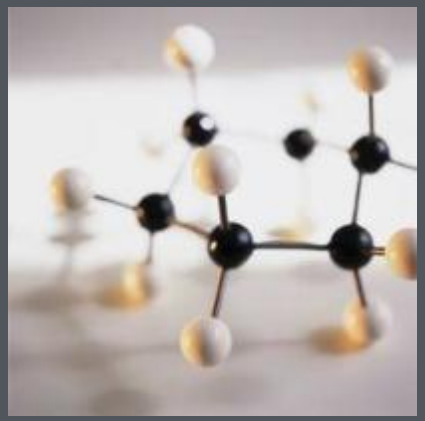
Innovative Topics for Advanced Biofuels

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Report-Out Webinar

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Cross-cutting Technology Areas:

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Hybrid Biochemical/Thermochemical Processing

Lignin Utilization

Direct Conversion to Fuel from Unconventional Sources

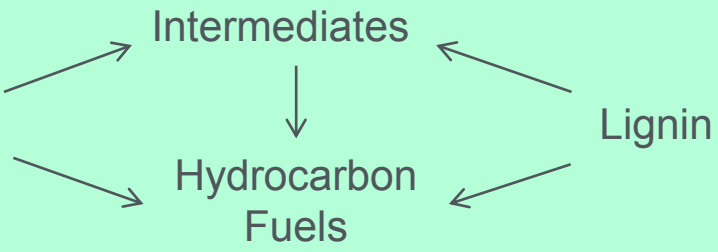
Solvent Systems in Biomass Conversion

Separation Systems in Biomass Processing

Conversion Systems for Genetically Modified/Optimized Feedstocks

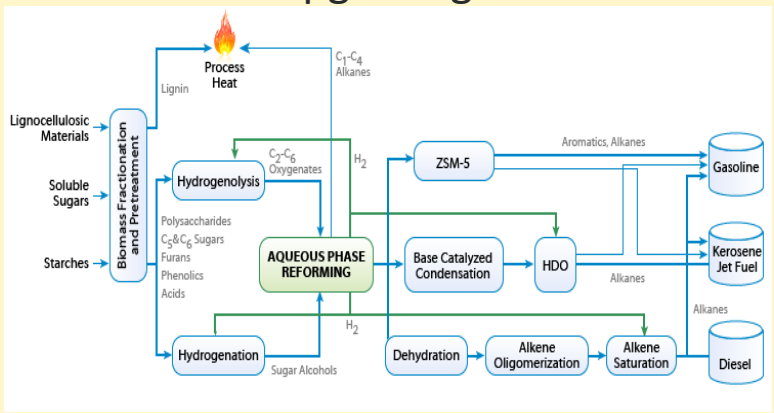
Hybrid Biochemical/Thermochemical Processing

HYBRID CONCEPT:



Ongoing Work

Enzymatic hydrolysis with catalytic upgrading



Syngas fermentation with catalytic upgrading of oxygenates

Gas reception Compression Fermentation Recovery Product Tank

Hybrid Biochemical/Thermochemical Processing

Challenges

- **Proliferation of Unit Operations –** *permutation of options non-obvious*
- **Successful Collaborations –** *biochemical & thermochemical researchers*
- **Energy and Flow Integration –** *heat integration, temperature swings potentially challenging and potentially costly; balancing batch with continuous operations*
- **Biological Upgrading of Thermochemically Derived Streams –** *TC sugar streams, bio oils*

Critical R&D Activities

1. Selective separation methods targeting products, intermediates, and poisons
2. Rational design of new enzymes and catalysts
3. Form hybrid process working group
4. TC production of chemical intermediates (HMF, CMF, LA)

Crosscutting R & D

Analysis – TEA tools enabling rational evaluation of hydrid processes

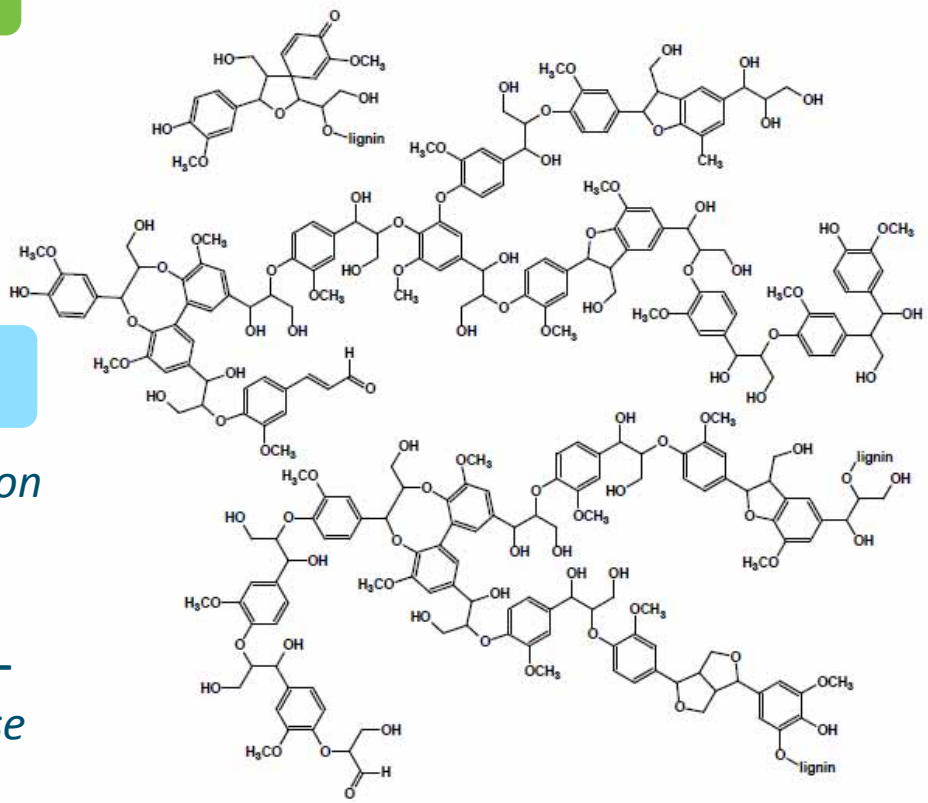
Catalysis – Biological and inorganic catalysts vary widely in requirements

Separations – Multi-prong approach to separation/fractionation

Lignin Utilization

Ongoing Work

- Modeling of lignin deconstruction during pyrolysis
- Chemical modification of lignin



Challenges

- **Hydrogen Requirements –** *and minimization*
  Post-Carbohydrate Usage – *how is lignin chemistry affected?*
- **Catalytic and Thermal Depolymerization –** *minimize coke, tar, char formation; increase selectivity and conversion to desirable precursors*
- **Programmatic –** *identify OBP's role in this space and coordinate with other efforts*

Lignin Utilization

Critical R&D Activities

1. Characterization of lignin across feedstock types and pretreatment regimes
2. Catalyst development for fuels/chemical synthesis
3. Development of value-added materials
4. Develop methods and standards for measuring and characterizing lignin

Direct Conversion to Fuel From Unconventional Sources

Ongoing Work

Techno-economic scoping
(Consolidated BioProcessing)

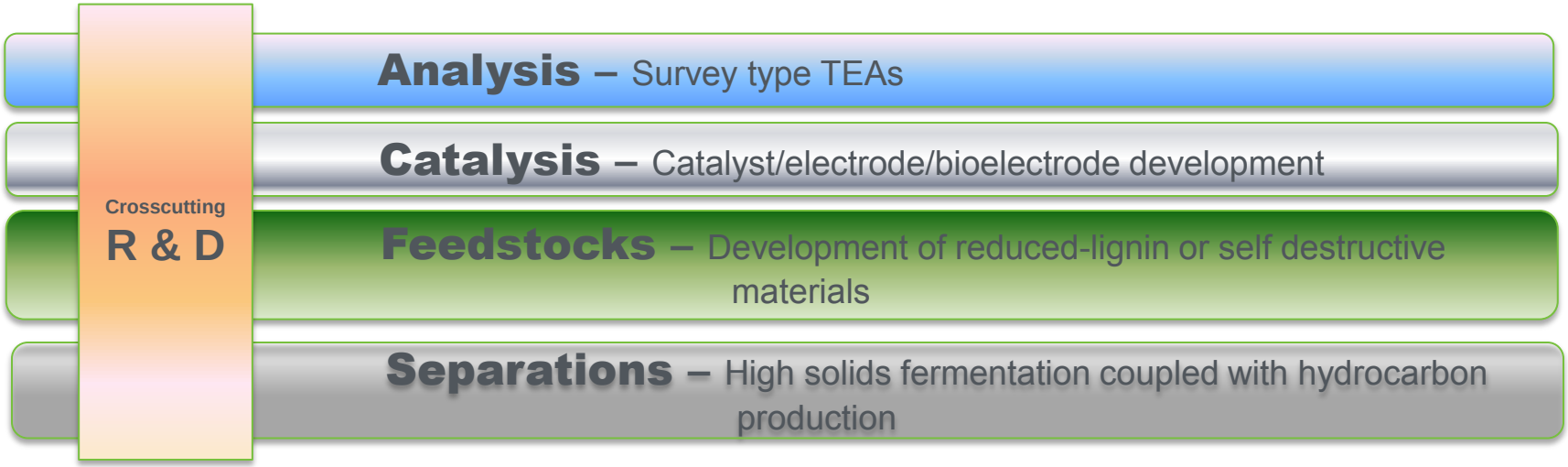
Challenges

- **Photoautotrophic Organisms –** *Obtaining/utilizing light; product secretion*
- **Electrofuels –** *Reaction rate; comparative energetics and CO_2*
- **Growth Kinetics –** *Identify OBP's role in this space and coordinate with other efforts*
- **Gas Diffusion/Exchange –** *Mass transfer of CO_2 into water; mass transport of gases*
- **Limited Data Availability –** *Majority of approaches are in their infancy*
- **Organism SOT –** *Suitable organisms may not have been identified or isolated yet. In addition, their performance in the presence of other dedicated organisms presents challenge*

Direct Conversion to Fuel From Unconventional Sources

Critical R&D Activities

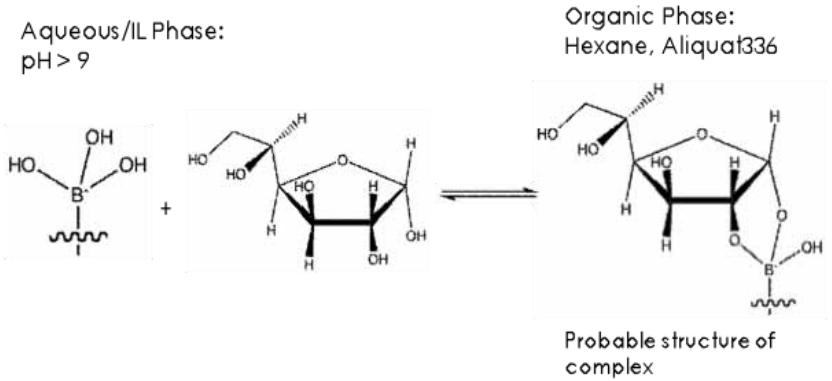
1. Modification of antennae systems
2. Photobioreactor engineering
3. Screen strains, identify extremophiles, coordinate with ARPA-e
4. Examine ruminant systems
5. Membrane development
6. Develop analytical tools for complex systems
7. Develop advanced Consolidated BioProcessing
8. Develop analytical tools for complex systems
9. Design microbes for growth on dense biomass



Solvent Utilization in Biomass Conversion

Ongoing Work

- Ionic liquids (JBEI, BASF)
- Organosolv
- Rapid hydrolysis & fractionation (PureVision)
- Leaching/reaction of trace species



Reaction scheme for recovering monomeric sugars from ionic liquids using a boronic acid extraction technique. (Brennan T.C., Blanch H.W., Simmons B.A., and Holmes B.M. Bioenergy Research (2010) 3:123-133)

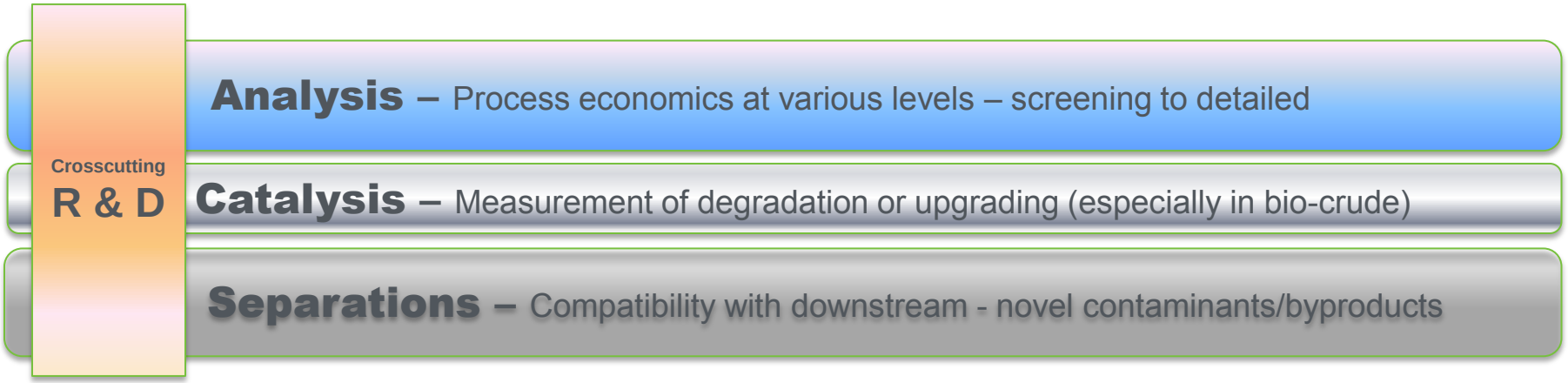
Challenges

- **Solvent Properties –**
  - *solvent toxicity and compatibility*
  - *solvent costs*
  - *solvent-specificity for the desired fractions/products*
- **Solvent use in Overall Process –**
  - *solvent recovery due to residual solubility, entrainment of ash, and particulates,*
  - *fractionation of Biomass*
  - *Use in bio-crude*

Solvent Utilization in Biomass Conversion

Critical R&D Activities

1. Solvent recovery
   - Better Process, downstream tests and compatibility, test residuals
2. Solvent Properties
   - Thermodynamic measurements, identify optimal solvents for product recovery, leverage knowledge from past industrial cellulose solvents
3. Feasibility of solvents within bio-crude upgrading
   - Improve C5 utilization/flux in target organisms
4. Demonstrate solvent recycling feasibility
5. Fractionation into biomass sugars to feed advanced biofuels



Separations Systems in Biomass Processing

Ongoing Work

- Bioreactor for continuous bioconversion and single-step separation
- Vapor phase filtration of pyrolysis vapors
- Membrane separation for C_5/C_6 sugar recovery
- Magnetic nanoparticles for sugar separation

Ceramic filter
0 cycles

Ceramic filter
1500 cycles

Challenges

- **Solids/Particulates Removal from Liquid and Vapor Systems**
  - *– lack of understanding of effects on agronomics (soil/carbon, pathogens risks)*
- **Removal of Acids, Organics, Char, and Water –**
  - *– from vapor and liquid phase systems*

Separations Systems in Biomass Processing

Critical R&D Activities

1. Vapor phase filters
2. Liquid phase membranes
3. Definition of process limits and process optimization
4. Equipment development and integration

Crosscutting R & D

Analysis – TEA to optimize systems within process limitation bounds

Catalysis – Tolerance for poisons/solids

Conversion Systems for Genetically Modified/Optimized Feedstocks

Ongoing Work

- Analytical methods and standards for establishing feedstock performance
- Bench and pilot scale testing support when sufficient quantities of modified feedstocks become available

Challenges

- **Unintended Consequence of GM –** *lack of understanding of effects on agronomics (soil/carbon, pathogens risks)*
- **Supply Chain –** *feedstock modifications can impact biomass supply chain (collection systems, storage characteristics, regulatory requirements)*
- **Process Design Engineering –** *redesign necessary to maintain and exploit feedstock modifications*
- **Programmatic –** *identify OBP's role in this space and coordinate with other efforts*

Conversion Systems for Genetically Modified/Optimized Feedstocks

Critical R&D Activities

1. Link DOE/USDA production platform work on variety modifications/optimization with conversion platforms
2. Develop new separation/collection systems/methods for modified feedstocks
3. Develop new/modify existing feedstock pretreatment to maintain built-in enzymes
4. Develop sustainability metrics/indices and practices for modified feedstocks
5. Current modified feedstocks target ethanol, opportunity to extend to hydrocarbons