The Center for Bioenergy Innovation

Convergent improvement of plants and microbes for feedstocks, fuels and products

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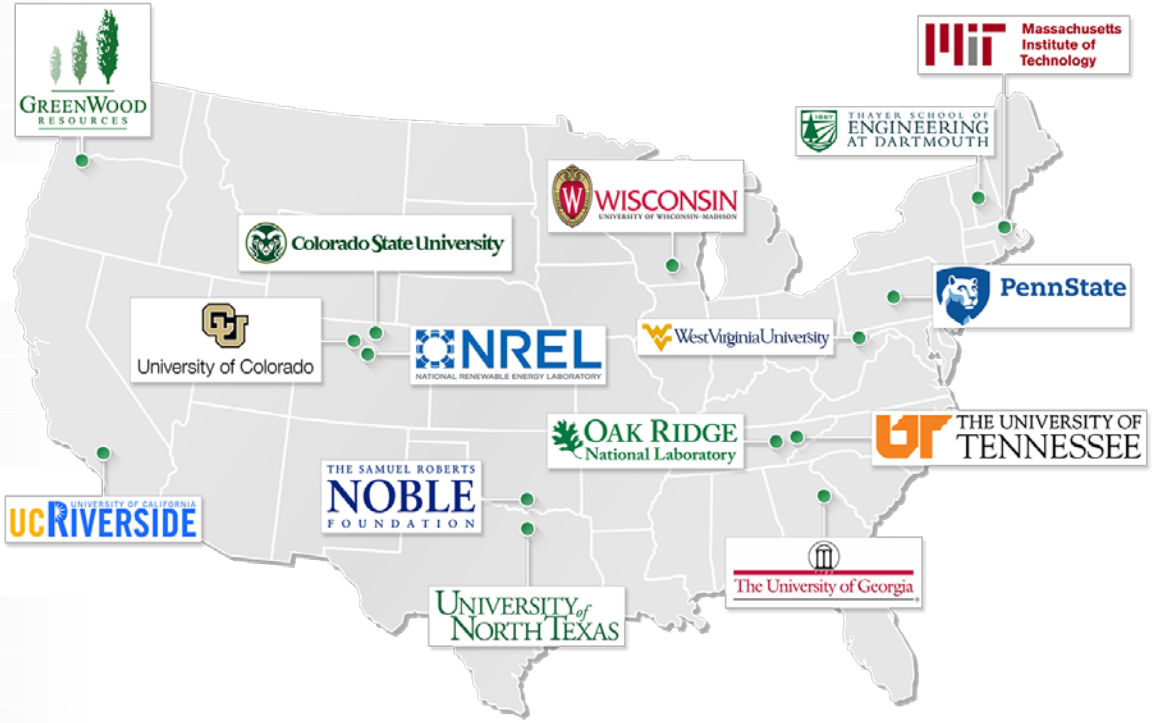
THE CENTER FOR BIOENERGY INNOVATION

U.S. DEPARTMENT OF ENERGY | Office of Science

CBI Partners and Expertise

CBI research partners:

- 2 National Laboratories
- 11 Academic Institutions
- 1 Research Foundation
- 1 Private Company
- 40% new PIs and/or Institutions



CBI organizing principles:

- Rapid Domestication
- Convergent Design
- Utilizing complex phenotypes

CBI research goals:

- Biomass yield
- Feedstock sustainability
- Feedstock uniformity
- End-product titer
- Microbial robustness
- Commercial-scale product yields

CBI's Vision: To accelerate domestication of bioenergy-relevant plants and microbes to enable high-impact innovations across the bioenergy supply chain

Research Targets

Create high yielding bioenergy crops, which display uniform productivity and increased sustainability, by harnessing natural diversity via genomic selection

Engineer Consolidated Bioprocessing (CBP) microbes to produce commercially relevant quantities of C4 alcohols and C6 esters

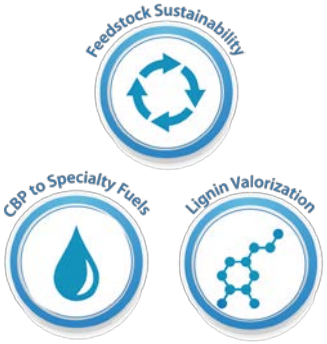
Transform lignin to enhance biological conversion for the production of co-product chemicals and novel materials

Research Domains

Accelerative Science

Integrative Analyses & Understanding

Use-Inspired Research



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CBI encompasses the four Science Focus Areas

Sustainability

Feedstocks

Deconstruction

Conversion

Sustainability

- Mechanistic understanding of crop interactions with biotic and abiotic environments
- Technoeconomic evaluation of biomass to fuels and products

Deconstruction and Separation

- Feedstock agnostic deconstruction
- Detailed understanding of plant cell walls during deconstruction
- Improved enzymes and approaches for biomass processing
- Multi-scale modeling of plant cell walls

Feedstock Development

- Enhanced feedstocks with improved yield, water use, and nutrient use
- Genetic tools and biosystems design approaches
- High-throughput analytical tools
- Field testing of new bioenergy feedstocks
- Quantitative models to predict feedstock performance

Conversion to Specialty Biofuels and Products

- High-throughput screens of strains and constructs
- Development of a broader set of platform microbes
- Enhanced microbial tolerance to toxins
- Technologies for CBP
- Improved feedstocks for fuels/products

CBI will simultaneously improve sustainability and feedstock traits

Sustainability
Feedstocks
Deconstruction
Conversion

Yield

Biomass per unit area per unit time
>50% improvement in biomass yield and biomass uniformity

Sustainability

Water-use efficiency (WUE)
<10% yield loss under drought

Nitrogen-use efficiency (NUE)
>20% improvement

Pest and pathogen resistance

Favorable microbial associations

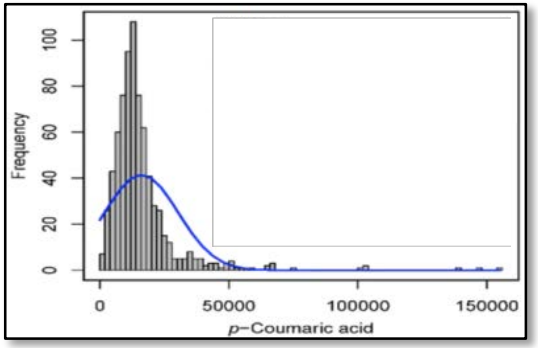
Feedstock uniformity

Biomass composition over time

Biomass composition across environments

Populus

Panicum



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Our approach allows us to use disruptive scientific methods to accelerate domestication of our feedstocks

Sustainability | Feedstocks | Deconstruction | Conversion

GWAS/PheWAS

- Forward genetics
- Reverse genetics

Genomic Selection

- Selection index based on technoeconomic assessment (TEA)
- Pleiotropy and epistatic networks

Genetic Engineering and Reverse Genetics

- Cisgenic
- Transgenic

Poplar and switchgrass natural diversity (GWAS populations) and diverse microbes → Phenotyping → Superior plant genotypes / Beneficial plant-microbe interactions / Important plant-microbe pathosystems → GWAS and gene function studies → Mechanisms of drought tolerance, WUE, NUE, and microbial interactions; Marker-assisted breeding; Beneficial microbes for sustainable plant production

TEA Output

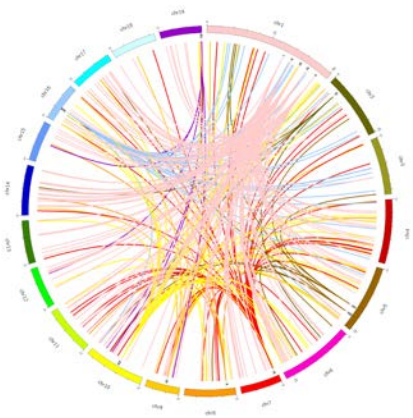
Productivity Metrics
Compositional Metrics
Sustainability Metrics

Aspen Plus
Cost
extendsim
Biomass Yield
SimaPro
Life Cycle Inventory

Value added per unit product output per modified trait

$\$ \cdot gal^{-1} \cdot phenotype^{-1}$

Regulatory Network Information

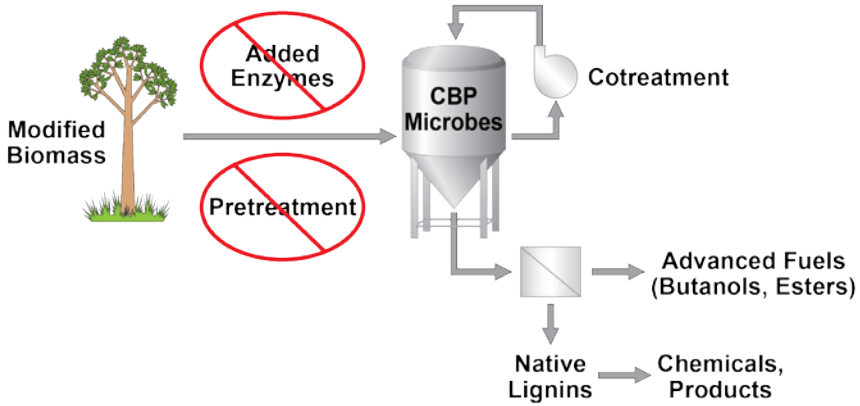


Populus **trans-eQTNs**

CBP with cellulolytic anaerobes and cotreatment will transform deconstruction and conversion

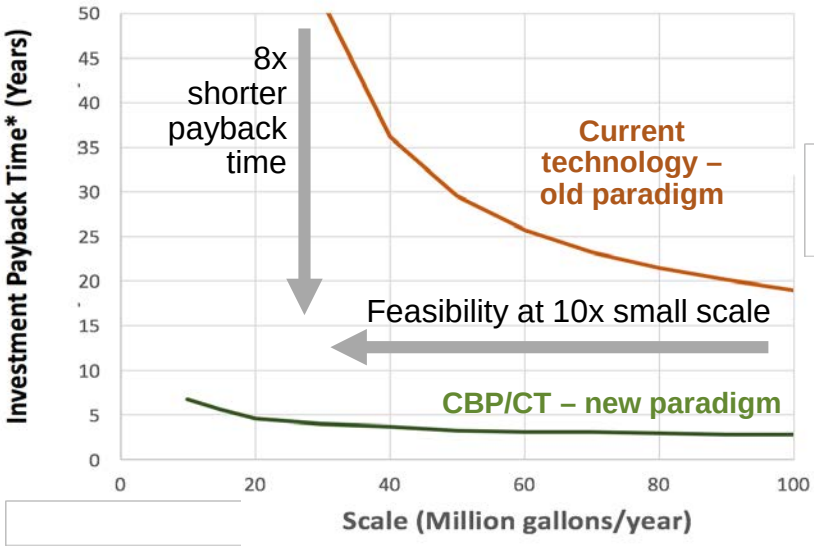
Sustainability
Feedstocks
Deconstruction
Conversion

Consolidated bioprocessing and cotreatment (CBP/CT) paradigm



Clostridium thermocellum

Potential disruptive impact of CBP/CT



CBI will deliver:
• >80% carbohydrate solubilization at >120 g/L solids loading • > 30 g/L iso- and/or n-butanol • Portfolio of valorized lignin products

Through the implementation of:
• Accelerated domestication approaches • Metabolic modeling and engineering • Synthetic biology

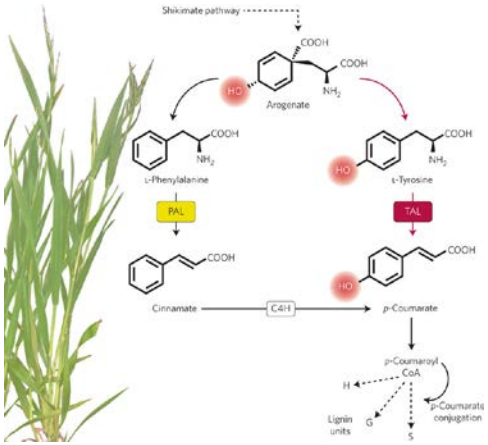
Convergent design and deconstruction of tailored lignin provides innovative opportunities for valorization

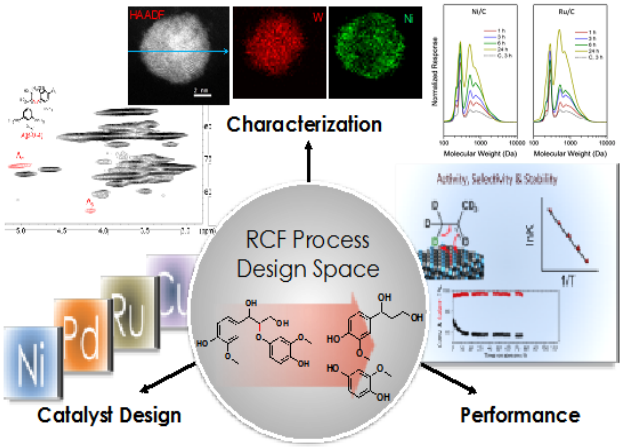
Sustainability

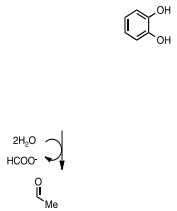
Feedstocks

Deconstruction

Conversion







Pseudomonas putida

In planta lignin modification

Maximizing the number of C-O bonds in lignin via genetic diversity and plant engineering will enable the production of lignin designed for deconstruction, leading to feedstock-agnostic lignin valorization approaches

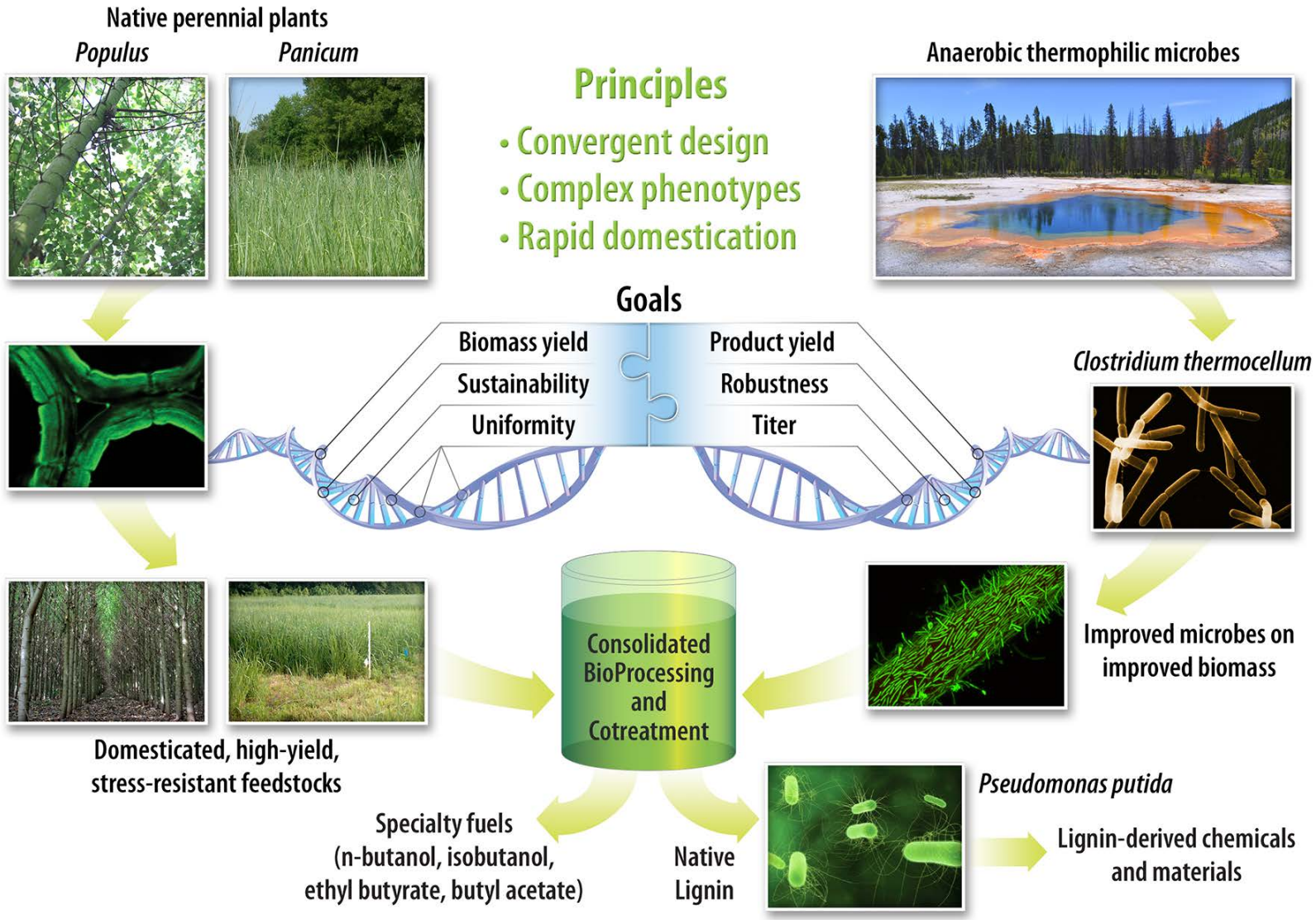
Reductive catalytic fractionation

CBP/co-treatment will enrich poplar and switchgrass in native lignin that can readily be solubilized and partially depolymerized via techniques that target C-O bonds and stabilize reaction intermediates as monomeric or oligomeric products

Biological Funneling

Microbial biocatalysts exist that 1) exhibit ligninolytic, aromatic-catabolic activities, 2) funnel heterogeneous aromatic monomers to central aromatic intermediates, and 3) produce target co-products from lignin via atom-efficient transformations

CBI Integrated Framework and Overview



Thank You – Questions and Comments