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C2B2

Colorado Center for Biorefining and Biofuels

Scientists Start at Grassroots To Fulfill Biofuels' Promise

A layperson might view the vast expanses of land on Colorado's eastern plains as nothing but arid scrubland, inhospitable to all but the heartiest plants and animals. To scientists like Daniel R. Bush, Barbara Demmig-Adams and Jan E. Leach, however, that acreage presents great promise. They envision this marginal, second-tier farmland as a proving ground for crops that could put the state and the Colorado Center for Biorefining & Biofuels (C2B2) at the vanguard of the biofuels movement.

What the three scientists have in mind is quite literally a grassroots effort that begins with the crucial work of identifying crops whose combination of characteristics makes them optimal to grow in Colorado's semi-arid climate as a feedstock for production of biofuels. "This is the first step—determining what the most promising plants are for making cellulosic biofuels," says Bush, professor and chair of the biology department at Colorado State University in Fort Collins.

Bush, Demmig-Adams, a highly cited researcher and professor in the department of ecology and evolutionary biology at the University of Colorado-Boulder, and Leach, a university distinguished professor at CSU, are proposing to test a wide range of grasses to determine which ones would be best suited to serve as starting material for biomass generation. As part of a project proposal submitted earlier this year to C2B2, they are seeking to identify grasses:

- that generate maximum yields with minimum inputs on marginal lands, using water, solar energy and other resources most efficiently;
- that prove most resilient, with the ability to flourish in less than ideal soil conditions and in a semi-arid climate where they will be subjected to potentially harsh elements — drought, heat, cold, wind, etc.
- that are pest-resistant; and,
- that have the right cellular composition to make their conversion into liquid fuel as efficient, sustainable, environmentally benign and straightforward as possible.

Why Grass?

Can such a nondescript plant as grass become a biomass powerhouse? Several factors suggest that it can. First, grasses can grow on marginal farmland rather than competing with food crops for increasingly scarce premium farmland. Second, as Demmig-Adams, an expert in how plants use energy, points out, the process of producing biofuels from cellulosic material such as grass emits significantly fewer greenhouse gases than production processes involving sugar cane, corn (maize) and the like. Grasses also are preferable from an agronomic and resource standpoint; raising certain strains may require less energy, water and overall nurturing. Perennial grasses, explains Bush, a plant physiologist and molecular geneticist, are particularly appealing because (1) they can capture and store essential nutrients such as nitrogen underground to bridge growth from one season to the next and (2) they sprout earlier in the season, leading to larger yields.

The project calls for multiple grass varieties, including switchgrass, *Miscanthus giganteus*, big bluestem, salt grass, sorghum hybrids and tumbleweed to be grown in both irrigated and rain-fed field plots, then tested for their biomass yield potential. The grasses would then be evaluated based on their photosynthetic rate, solar energy conversion efficiency and biomass yield to identify those with the greatest potential to grow as high-yielding energy crops under limited-water conditions. Findings from the project might be of particular interest to Colorado farmers, Bush points out. "For them, it could mean another source of income."

Once the crops with the greatest potential are identified, scientists then can turn their attention upstream, to pursuits aimed at optimizing the plants for commercial production as a biofuel feedstock. That work likely would include genetically manipulating the plants to make them even more pest-resistant, more efficient in the processing of water and nutrients, more tolerant to temperature extremes and simpler to process from an engineering standpoint.

Collaboration is Critical

From the grassroots to the consumer, developing the plants and processes necessary to bring new biofuels to market is an eminently feasible undertaking, the scientists agree. However, according to Leach, whose expertise lies in crop plant genomics and pest resistance, it will require extensive collaboration among a diverse group of experts, from biologists and engineers to economists, plus substantial funding support. "To bring the grasses to the point of being a crop plant, i.e., something we know how to produce on a large scale efficiently, will require massive amounts of input in terms of science time and financial investments."

A combination of collaborative spirit and funding availability makes C2B2 particularly well-positioned to catalyze fast progress in the biofuels arena, Bush says. He is optimistic that the grass proposal will be supported by one of C2B2's members through sponsored research or a third party, private or public. It shouldn't be long after that before the results start sprouting. "It's realistic to think that in ten years we'll have crops in the field, and the processes and infrastructure in place to really make a difference."

C2B2 Seed Grant Proposals

The mission of C2B2 is to improve fundamental understanding and develop new technologies in areas relevant to the future commercialization of integrated, sustainable biorefining and biofuels processes. To further this mission C2B2 solicited proposals from all four participating institutions for highly innovative research projects covering all aspects of converting renewable resources. Here is a list of all 67 proposals and details on several. Initially ten projects were funded and are highlighted in **bold.**

For more information visit www.colorado.edu/che/c2b2 or contact Dave Powell, Business Outreach Coordinator at either 303-709-8929 or c2b2@colorado.edu

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Research seeks to identify naturally occurring varieties with superior temperature tolerance. These varieties can then be used for field testing and, if necessary, for breeding and/or engineering approaches to further improve tolerance and/or combine enhanced photoprotection with other desired traits.

Goals are to develop a plant regeneration system for Miscanthus (a potential energy crop) using tissue culture methods, and to identify robust stable transformation technologies for Miscanthus to introduce and manipulate desirable genes.

Goal is to identify origin and physiological roles of glycosylhydrolases that degrade cellulosic substrates for conversion of biomass to biofuel. This research will explore patterns of expression of genes encoding glycosylhydrolases during degradation of different substrates and at different times during degradation, and to begin to characterize the substrate specificities and optimal conditions for glycosylhydrolases in the target organism.

Optimal long-term bioconversion based biofuels processes will be able to efficiently utilize a wide variety of different biomass sources, ranging from forestry residues to mainstream to engineered crops. Here, we propose preliminary studies towards the development of an efficient and rapid method for assessing growth and production potential of platform organisms on a wide variety of different sources of biomass that have been treated using various pre-treatment strategies.

The goal of this work is to manipulate high solids biomass slurries using drag reduction and viscosity control technologies to improve energy efficiency during processing and increase volume and fuel quality of the product streams.

PLANT BIOLOGY AND CROPS SCIENCE

Borch, Thomas - CSU • Environmental Iimpact of Distiller's Grains in Livestock Feed: Quanitification of Nitrogen, Phosphorous and Antibiotics in Cattle Manure

Bush, Daniel - CSU • Enhancing Yield in Sugar Beet as a Model Energy Crop*

Bush, Daniel - CSU • Identifying Promising Energy Crops for Colorado

Darzins, Al - NREL • Establishment of a Bioenergy-Focused Microalgae Strain Collection Using Rapid, High-Throughput Methodologies*

Demmig-Adams, Barbara - CU • Increasing Algal Productivity by Maximizing Solar Energy Conversion Efficiency

Demmig-Adams, Barbara - CU • Screening for Switchgrass and Poplar Varieties with Improved Tolerance to Both Heat and Cold

Leach, Jan - CSU • Identifying Traits for Increased Biomass Production in Marginal Environments

McKay, John - CSU • Optimizing Brassica Oilseed Yield for Biofuel Under Drought: Extending Functional Genomics from Arabiopsis to Brassica

Pilon, Marinus - CSU • Regulation of Energy Metabolism by Micronutrient Availability via micro-RNA Mediated mRNA Decay in Plants: Targeted Alteration of Lignification

Reddy, A.S.N. - CSU • Cloning of a Transcription Factor Involved in Controlling Plant Biomass from Miscanthus

Reddy, A.S.N. - CSU • Development of an In Planta System to Deconstruct Lignins Using Enzymes from White Rot Fungus

Reddy, A.S.N. - CSU • Development of Regeneration and Transformation Technologies for Miscanthus

Westra, Phil - CSU • Kochia (Kochia Scoparia) as a Candidate Biofuel Plant for the Central Great Plains

BIOCHEMICAL ENGINEERING

Bortz, David - CU • Design of Microbial communities for Hydrogen Production

Copley, Shelley - CU • Exploration of the Evolution and Physiological Role of Cellulases

Gill, Ryan - CU • A High-Throughput Screen of Fermentation Potential

Gill, Ryan - CU • Biofilm Engineering for Improved Production of Cellulosic Biofuels*

Jimenez, Ralph - CU • Multifunctional, High-Throughput Optical Screening of Fuel-Producing Microbes*

Kompala, Dhinakar - CU • Conversion of Glycerol to 1,2-Propylene Glycol by Metabolically Engineered Bacteria

Reardon, Kenneth - CSU • Bioconversion of Extracted Algal Biomass into Ethanol

Reardon, Kenneth - CSU • Proteomic Investigation of the Mechanisms for Lipid Storage in Microalgae*

Vivanco, Jorge - CSU • Screening of a Multi-species Microbial Pool for Enzyme Consortia Associated with Lignocellulose Degradation

PROCESS ENGINEERING

Davis, Robert - CU • Sugar and Enzyme Recovery During Saccharification with High Solids Loading*

Falconer, John - CU • Separating Alcohol/Water Mixtures Using Sub-2 nm Highly Hydrophobic Carbon Nanotube Membranes

Gin, Douglas - CU • Lyotropic Liquid Crystal Polymer Membranes for the Molecular-Size-Selective Removal of Water from Bioprocess Product Mixtures

Liberatore, Matthew - CSM • Rheological Control and Drag Reduction in High Solids Cellulosic Slurries

Liberatore, Matthew - CSM • Rheology and Transport of Bio-Oils

Liberatore, Matthew - CSM • Separation of Bio-Oil for Chemical and Fuel Production

Maciel, Gary - CSU • In Situ Examination of the Potential Role of Supercritical Fluid (SCF) Treatments in Conversions of Biomass Resources

Noble, Richard - CU • Alcohol/Water Separations Using IL-Based Polymer Membranes*

Noble, Richard - CU • Extracting Alcohol from Water by Tuning the Nanostructure of Hydrophobic MFI Zeolite Membranes

Noble, Richard - CU • High Flux Separation of 1,3-Propanediol from Aqueous Solutions Using Pervaporation through Inorganic Membranes

Pellegrino, John - CU • Studies of Force-application for Oil Extraction from Biomass

PROCESS ENGINEERING (con't)

Schwartz, Daniel - CU • Improving Two-Phase Biodiesel Reactions through Interfacial Engineering

Spear, John - CSM • Effect of Concentration andTemperature of Ethanol in Fuel Blend on Microbial and Caustic Corrosion of High Strength Steels

Wickramasinghe, Ranil - CSU • Membrane Extraction for Future Biorefineries

Wickramasinghe, Ranil - CSU • Lignin, recovery and utilization

Goal is to explore whether membrane extraction is an attractive unit operation for recovery of lignin from pretreated lignocellulosic hydrolysates and whether the recovered lignin can be utilized to produce value added products.

THERMOCHEMICAL ENGINEERING

Daily, John - CU • Impact of the Thermal Conversion of Model Sugars on Tar Formation During Gasification

Dean, Anthony - CSM • Experimental Characterization of Bio-Oil Atomization

Falconer, John - CU • Preparation and Testing of a Hybrid Catalyst for LPG Production from Syngas

Atomic layer deposition will be employed to modify zeolite catalysts with nanoscale precision, potentially creating a material capable of direct conversion of synthesis gas to alkanes.

Herring, Andrew - CSM • Development of Factor Analysis Based Procedures to Simplify GC-MS Analysis of Complex Mixtures such as Biomass Pyrolysis Products

Herring, Andrew - CSM • Laser Pyrolysis Screening of Biomass Feedstock and Thermochemistry for the Production of Fuels and Chemicals

Herring, Andrew - CSM • Novel Catalysts for Biodiesel synthesis and modification

Medlin, Will - CU • Preparation and Modification of Supported Catalysts Using Ruthenium ALD

Papas, Paul - CSM • Hydrogen Production Process from the Iron-Steam Reaction coupled with Char/Biomass Gasification

Phillips, Steven - NREL • An Alternate Pathway to Thermochemical Ethanol and Hydrogen via a DME Intermediate

Phillips, Steven - NREL • Improvede Thermochemical Ethanol Production Using Solid-Phase Sorbents for Carbon Dioxide Removal from Biomass-derived Syngas

Richards, Ryan - CSM • Heterogenous Catalysis of the Transesterification of Vegetable Oil Biodiesel via MgO(111) Nanosheets

Simpson, Lin - NREL • Novel Catalysts for Biofuels Processing

For this effort, NREL proposes to integrate advanced computational first principles modeling with novel nanomaterials synthesis to intelligently identify and create a new class of high performance biofuels catalysts using partially coordinated metals.

Weimer, Alan - CU • Rapid Solar-thermal Conversion of Algae to Syngas*

PRODUCT ENGINEERING

Bianco, Roberto - CU • Theoretical Study of the Catalytic Conversion of Glycerol to 1,2-propanediol

Dean, Anthony - CSM • Accurate Kinetic Models for Biodiesel Ignition

The goal is to develop a validated, fundamentally based mechanism that can describe the ignition kinetics of a model biofuel/hydrocarbon blend (methyl butanoate/heptane) under conditions that are relevant to diesel engines.

Dorgan, John - CSM • Biorefinery Integration through Coproduction of Bioplastics*

Dorgan, John - CSM • Learning from Natural Gas Hydrates: Kinetic Inhibitors for Eliminating Cold Filter Plugging in Biodiesels

Gin, Douglas - CU • Nanostructured Sulfonic Acid Resin Catalysts for More Selective Glycerol Dehydration and Hydrogenolysis

In this research, the goal is to develop nanostructured catalysts capable of improved selectivity in the production of diols from glycerol. The promise of these materials is that their well-ordered structure promoted more specific catalyst-reactant interactions.

Marchese, Anthony - CSU • Biodiesel Droplet Ignition and Prompt NOx characterization Studies

Papas, Paul - CSM • A High Pressure Flat-Frame Reactor for Studying Biomass/Coal Conversion or Liquid Biofuel Combustion

SYSTEMS ENGINEERING

Fall, Ray - CU • Real-Time Monitoring of Biomass Accumulationi and Insect Herbivory in Bio-/fuel Crops with Parallel Prediction of Regional Impacts on Air Quality

Helmig, Detlev - CU • Biogenic Volatile Organic Compound Emissions from Biofuel Farming and Their Effect on Air Quality

McKinnon, J. Thomas - CSM • A Field-to-Wheel Systems Optimization and Process Design for a Thermochemical Lignocellulose-to-Biofuels Plant*

Munoz, David - CSM • The 3Rs - Renewables, Recruiting, and Racing!

Pellegrino, John - CU • Techno-economic Modeling of Membrane Systems to Guide Process Innovations

Phillips, Steven - NREL • Techno-Economic Evaluation of Low-Grade Heat Recovery to Improve Ethanol Yield and to Reduce Water Consumption During Thermochemical Ethanol Production

Phillips, Steven - NREL • Techno-Economic Evaluation of Low-Grade Heat Recovery to Reduce Water Consumption During Biochemical Ethanol Production

The proposed studies will establish the economics of using low temperature heat recovery alternatives in biochemical and thermochemical ethanol production.

Pritchett, James - CSU • Strategic Assessment and Regional Economic Impact Analysis of Biofuel Cropping in Colorado's South Platte Basin

This proposal assesses rural Colorado's ability to provide bioenergy crops and valueadded processing, evaluates the economic impact of bioenergy crops on rural communities and considers the tradeoff between bioenergy and food crop production.

*** these projects/PIs have been selected for funding after two stages of review**

Sponsors

ASD Inc.
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MARK THE DATES

Jan. 2008: Next C2B2 Newsletter
Feb. 10-12, 2008: Next C2B2 Meeting

C2B2 is a cooperative research and educational center devoted to the conversion of biomass to fuels and other products, supported by state, institutional, and industry funds. The mission of C2B2 is to become the world's leading center in biorefining and biofuels research and education.

We provide private industry with one-stop access to researchers, laboratories, students, and educators from four innovative institutions, each having unique strengths in biofuel and biorefining application areas.

Colorado Renewable Energy Collaboratory
Created to develop energy technologies for rapid commercialization, the Collaboratory consists of the following institutions:

University of Colorado at Boulder
Ranked in the top 25 nationally in Chemical and Biological Engineering, Molecular and Cellular Biology, and Biochemistry.

Colorado State University
Ranked in the top 10 nationally in Agricultural Sciences with an internationally renowned Engines and Energy Conversion Laboratory.

Colorado School of Mines
One of the few universities uniquely focused on energy research.

National Renewable Energy Laboratory
The only national laboratory dedicated to renewable energy and energy efficiency research and development (R&D).

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