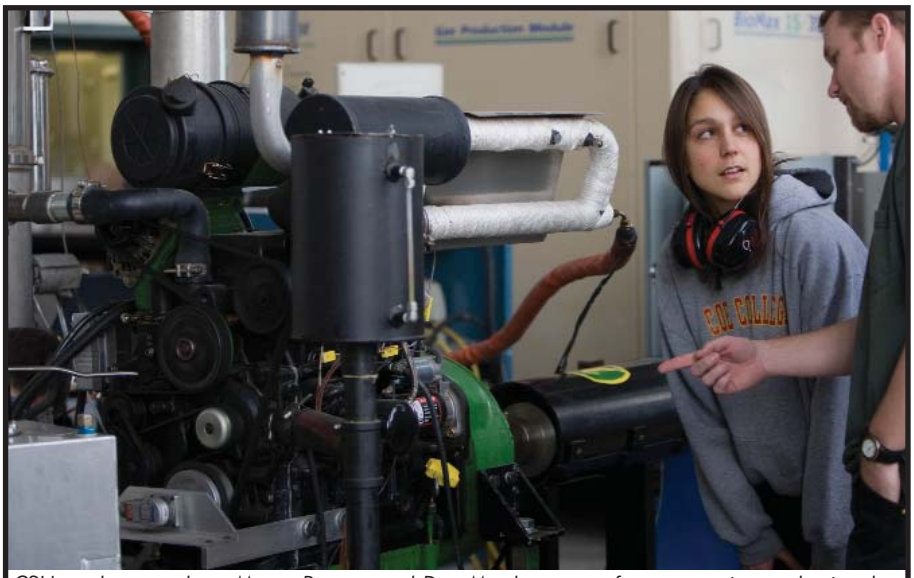
C2B2
Colorado Center for Biorefining and Biofuels
fall 2008

Can Biofuels Power the Engine of Progress? CSU Lab Aims to Find Out



CSU graduate students Maren Bennett and Dan Mastbergen perform an engine study aimed at quantifying the particulate matter size distribution in a non-road diesel engine operating on biodiesel blends. Photo courtesy of photographer Dan Bihn and the EECL.

There's a reason more than 40 researchers and staff at Colorado State University's Engines and Energy Conversion Laboratory like coming to work everyday. "You feel the excitement and enthusiasm right when you walk through the door," says Anthony J. Marchese, Ph.D., a relative newcomer at the lab, having joined the CSU faculty earlier this year as an associate professor in the Department of Mechanical Engineering.

Marchese, whose work at the EECL is focused on evaluating various strains of algae as potential feedstocks for production of less-polluting, next-generation biofuels, says he and other faculty and student researchers at the lab are inspired by the potentially far-reaching scope of their work. "We're focusing on finding energy solutions that can have a broad global impact. That's almost a prerequisite for the problems we work on."

Founded 15 years ago mainly to develop cleaner-burning, more efficient stationary diesel and natural gas engine technology, the EECL has taken its work in a variety of new upstream and downstream directions, particularly in the last five years, under the leadership of founder Dr. Bryan Willson. While the lab remains committed to advancing engine technology, with ongoing work aimed at advancing ignition systems (laser, micropilot, pre-combustion chamber) and after-treatment (SCR, 3-way catalysts, NSCR, oxidation catalysts), it has diversified its pursuits to include:

- designing low-cost, high-performance cookstoves for the developing world (through EECL's Global Innovation Center);
- aiding in research whose goal is optimizing the electric grid for renewable and distributed power; and,
- a new emphasis on biofuels and renewable fuels.

In 2006, for example, it founded Solix Biofuels Inc., a C2B2 Sponsoring Member company that is working to commercialize technology for producing biodiesel from oil derived from algae. Current biofuels research at the EECL includes a major R&D program with Solix to develop photobioreactors for the mass production of algae as a biodiesel feedstock.

There are several reasons algae is especially promising as a feedstock, Marchese explains. First, it doesn't compete with the global food supply, unlike other feedstocks such as corn and soybeans. Second, from a yield standpoint, algae can be much more efficient than other feedstocks; current estimates suggest it may be possible to produce between 10,000 and 20,000 gallons of biofuel per acre of algae, compared to 60 gallons per acre for soy biodiesel. And third, the processes for deriving biofuels from algae can be significantly more energy-intensive than those associated with biofuels made from soybeans and the like. "Some strains of algae have shown an ability to produce 70% their [dry] weight in oil," notes Marchese. That suggests that some microalgae strains can be converted to biofuels using much less energy.

While these apparent advantages are sparking broad interest in producing biofuels from algae, a commercially viable process for doing so remains a long-term goal, he says. "We're not six months away, we are years away from making this feasible."

That's not deterring Marchese and his EECL colleagues, however. Marchese, whose specialty is combustion chemistry, is working with Solix Biofuels on a project to investigate how the chemical structure of algae strains affects emissions of oxides of nitrogen (NOx) and particulate matter (PM). The project involves modeling the emissions performance of diesel engines running on fuels derived from various algae strains. The next step, he says, is to investigate how those fuels actually perform in test engines. Marchese says he hopes soon to secure funding for a study to examine the effect of the chemical structure of algal bio-crude feedstocks on diesel pollutant formation in a 56-hp John Deere 4024T diesel engine operating on algae-derived FAME (fatty acid methyl esters) biodiesel. Among the hundreds of algal strains being evaluated for full-scale production of algal bio-crude, the goal is to identify those that show an ability to sharply reduce NOx and PM emissions relative to conventional diesel fuel as well as other biofuels like ethanol.

JOIN US IN PHILADELPHIA!

C2B2 Energy Networking Reception

American Institute of Chemical Engineers
Centennial Celebration Annual Meeting

Monday, November 17, 2008 • 5:00 PM • Salon G
Marriott Philadelphia Downtown, Philadelphia, PA

C2B2 2008 Seed Grant Proposals

Each year C2B2 seeks to further fundamental understanding and develop new technologies relevant to the future commercialization of sustainable biorefining and biofuels processes. This aim is achieved through our annual solicitation for and selection of research proposals for the C2B2 Seed Grant program. A total of 45 proposals were submitted by approximately 70 C2B2 principal investigators in response to the 2008 Request for Proposals and are listed in alphabetical order by research thrust area below; brief descriptions of several 2008 Seed Grant proposals are highlighted and the 12 proposals selected for funding beginning in January 2009 are delineated in **BOLD**.

Generating transgenic Chlamydomonas with over-expressed glycerol transporters

Seeks to build a microfluidic cytometer to obtain: a cell-by-cell resolved profile of growth; extent of light absorption/utilization; lipid production in 1 microliter samples at a rate of thousand cells per minute; protocols for quantifying lipid content of single diatom and green algal cells with commercial fluorescent probes.

Goal is to use proteomics, lipidomics, and bioinformatics to develop an approach for discovery of enzymes and pathways used by algae to synthesize lipids.

To develop computational tools for automated analysis of genome- and metagenome-scale datasets of genes/organisms associated with desirable outcomes, e.g. efficient breakdown of feedstocks and biosynthesis of industrially desirable products, and/or toxicity resistance of metabolic intermediates/end products.

1) Demonstrate the complete isomerization & fermentation of xylose by brewer's yeast S. cerevisiae growing on a mixture of glucose and xylose; 2) evaluate economics of the approach; 3) compare results with the economics of xylose fermentation using metabolically engineered microbes.

Goal is to develop a process for the conversion of post-oil extraction algal biomass to ethanol using enzymatic and fermentation bioreactors. The reactor system performance will be assessed by the productivity and concentration of ethanol.

Seeks to develop a quantitative mass balance for indirectly-heated steam gasification of a lignin-rich fraction from woody biomass in bubbling fluidized bed & to characterize the gaseous products of the gasification reaction and the feasibility of producing a product gas high in hydrogen.

To explore the use of ALD for the modification of zeolites with catalytically-active metal oxide nanofilms or nanoparticles, and to identify the relationship between catalyst composition and performance in mixed alcohol synthesis and the LPG process as a function of operating conditions.

Seeks to improve the cold flow properties & blend for lower NOx emissions in biodiesel by discovering a heterogeneous catalyst for transesterification reactions with advantageous characteristics: 1) will not degrade during stirred reactions; 2) is readily separated from reaction mixtures; 3) enhances production yields/economics.

To conduct a proof-of-concept experiment on a novel reactor for the steam reforming of pyrolysis oil into clean synthesis gas; reactor configuration is designed to generate the minimum amount of solid carbon (coke) & reduce the steam-to-carbon ratio.

Objectives are to 1) explore the use of metal ALD to modify catalysts consisting of a single primary active metal to create bimetallic catalysts with excellent control over surface composition, and 2) to identify the relationship between catalyst composition and performance in two key reactions catalyzed by supporting metals including biomass tar reforming and conversion of glycerol to ethylene glycol & propanediols.

FEEDSTOCK ENGINEERING, PLANT BIOTECHNOLOGY & CROP SCIENCE

Ali, Gul Shad - CSU • In Planta Deconstruction of Hemicelluloses with Fungal Hydrolytic Enzymes

Chisholm, Stephen - CSU • Characterization of Small RNA Profiles in a High Oil-Content Microalgae

Demmig-Adams, Barbara - CU • Optimization of Algal Production of Glycerol as a Precursor for Transport Fuels

Demmig-Adams, Barbara - CU • Review of Feedstock Generation Potential of Algae

Jimenez, Ralph - CU • High Throughput Measurements of Algal PhotosyntheticEfficiency, Growth, and Triacylglycerol Content with a Lab-on-a-Chip Cytometer

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

Pilon, Marinus - CSU • Manipulation of Copper-regulated and MicroRNA-mediated Resource Allocation in Plants: Effects on Photosynthesis, Biomass, Flowering and Seed Set

Reardon, Ken - CSU • Elucidation of Algal Lipid Biosynthesis Pathways Using Proteomics and Lipidomics

Wickham, David - CSM • Innovative Catalytic Systems for Lignocellulose Hydolysis

Wolfrum, Ed - NREL • Rapid Fatty Acid Profile Fingerprinting in Microalgae Using py-GC-MS and py-MBMS

BIOCHEMICAL ENGINEERING

Henry, Charles - CSU • Improved Lipidomic Methods for Characterizing Biofuel Algae

Knight, Rob - CU • Bioinformatic Tools for the Parallel Assessment of Genomic and Meta-genomic Data

Kompala, Dhinakar - CU • Simultaneous Isomerization & Fermentation of Xylose and Glucose Mixtures into Ethanol

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

Weir, Tiffany - CSU • Pilot Biofermentation and Laccase Enzyme Characterization of Lignin Degrading Fungi from the Neotropics

Wu, David T. - CSM • Optimized Algal Enzymes for Lipid Biosynthesis via Molecular Simulation

THERMOCHEMICAL ENGINEERING

Baldwin, Robert - NREL • Gasification of Lignin from Lignocellulosic Biomass

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

Herring, Andrew M. - CSM • Improving the Steam Reforming Catalysts for Biomass Pyrolysis Oil

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

Marchese, Anthony J. - CSU • Characterization of Pollutant Formation from the Combustion of Algae-Derived Vegetable Oil, Biodiesel and Renewable Diesel

McKinnon, J. Thomas - CSM • A Novel Moving-Bed Reactor Configuration for Steam Reforming Pyrolysis Oil

Medlin, Will - CU • Preparation and Modification of Ru Catalysts with ALD

THERMOCHEMICAL ENGINEERING (con't)

Olsen, Daniel B. - CSU • SVO Profile Optimization for Direct Injection Compression Ignition Engine Performance

Richards, Ryan M. - CSM • Catalyst Engineering for Thermochemical Biomass Conversions to Fuels

Aims to assess whether a broad portfolio of nanostructured catalyst compositions have potential as models for future biomass conversion technologies. Optimized second generation catalysts will be designed based on structure/activity data from the initial portfolio.

Simpson, Lin - NREL • New Catalytic Materials for Conversion of Biomass-Derived Syngas to Fuels

Goal is to develop improved fuels synthesis catalysts by 1) identifying low cost structures/materials, 2) determining the viability of materials or molecule catalysts with low particle migration or degradation, 3) developing structures/materials with high specificity to decrease undesired materials formation.

Taylor, Patrick - CSM • Laboratory System to Evaluate the Fundamental Behavior of Microwave Plasma Enhanced Methane and Hydrogen Production from Wastes

Investigates rapid pyrolysis of "clean" cellulose and hemicellulose fractions from woody biomass in a bubbling fluidized bed reactor system and characterizes reaction products in terms of acidity and stability in order to assess upgrading requirements for bio-oil to a bio-crude.

PROCESS ENGINEERING

Baldwin, Robert - NREL • Pyrolysis of Fractionated Lignocellulosic Biomass

Falconer, John - CU • Separating Alcohol/Water Mixtures Using Carbon Nanotube Membranes

To grow CVD vertically-aligned, carbon nanotubes with small diameter pores; make thinner membranes; optimize procedure for conversion to dense membranes; and test the membrane's ability to extract alcohols from water by pervaporation.

Gin, Douglas - CU • Study of New Polymer Membranes with Uniform, Sub-1-nanometer Pores for Molecular-Size-Selective Removal of Water from Bioprocess Product Mixtures

Aims to explore the use of a new type of NF membrane with an ordered 3-D network of uniform, sub-1-nanometer size water pores for the selective separation of water from aqueous mixtures of (bio)organic molecules commonly produced in bioprocesses.

Herring, Andrew M. - CSM • New Solid Acid Catalysts for Bio-diesel Production

Hrenya, Christine - CU • Biomass Fluidization in a Circulating Fluidized Bed

Liberatore, Matthew - CSM • Viscosity Modification of High-Solids Lignocellulosic Slurries

Qian, Xianghong - CSU • Catalytic Membrane Bioreactor for Simultaneaous Transesterificiation and Glycerol Removal

Seeks to 1) apply combinatorial chemistry concepts to the computational design of corrosive base replacement catalysts for biodiesel production, 2) graft PSSA nanostructures from hydrophilic silica membrane surfaces using polymerization to test for transestification and glycerol removal.

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

Stickel, Jonathan - NREL • Enzymatic Hydrolysis as a Continuous Process: Separation of Lignin

To demonstrate continuous enzymatic hydrolysis, addressing lignin residue separation by 1) performing hydrolysis with the cellulose fraction obtained from a biomass fractionation process, with the use of an insoluble lignin separation step, 2) comparing continuous processes to batch saccharification.

Sum, Amadeu K. - CSM • Molecular Modeling as a Tool to Understand and Optimize Lipid Processing from Algae Production

Wickramasinghe, Ranil - CSU • Membrane Extraction for Future Biorefineries

To demonstrate that membrane extraction is an attractive separations technique for removal of acetic acid from pretreated lignocellulosic hydrolysates; optimizing the organic phases for maximum acetic acid extraction/efficiency.

PRODUCT ENGINEERING

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

To establish the feasibility of producing cellulosic whiskers during the hydrolysis of cellulose associated with deriving wood sugars for fermentation processes; to produce new bioplastics blends/composites and characterize their thermal/mechanical properties; to calculate life cycle properties of biobased materials.

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

Aims to explore the use of an ordered, nanoporous strong Brønsted acid resin made from lyotropic liquid crystals (LLCs), as a potentially more selective and efficient heterogeneous glycerol dehydration catalyst for 1,2-PDO production.

Medlin, Will - CU • Design of Bifunctional Catalysts for Carbohydrate Conversions

SYSTEMS ASSESSMENT AND ANALYSIS

Archibeque, Shawn - CSU • Expanded Economic Opportunities for Algae-based Biofuel Production, Using the Remaining Extract as a Feed for Animals

Provides data on the changes in nutrient provisions associated with feeding algae extract on nutrient use, and potential animal impacts.

Archibeque, Shawn - CSU • Enhancing Livestock Economic Opportunities by Production of Biofuel Co-products

Lewis, William - CU • A Test of the Viability of Anabaenopsis elenkenii for Production of Biofuel Feedstocks

Will quantify the pathways of carbon and energy for an atypical phytoplankton community (mixotrophic algae) and determine fuel production capabilities based on harvest potential and gaseous carbon fluxes to the atmosphere which offset sequestration in biomass.

Li, Chen - CU • A Multi-stage Solar Heat System for Biofuel Producing Process

Aims to investigate the use of solar heat to provide needed hot water and steam for biofuel production by developing a system of multi-stage evaporators to generate 3MW heat for the production of 50 million gallons of ethanol per year.

Colorado Renewable Energy Collaboratory
Partners for Clean Energy

National Renewable Energy Laboratory

Sponsors

C2B2 welcomes NEW Sponsoring Members: **Gevo • Valero**

Archer Daniels Midland Company
ASD
Aurora Biofuels
BioExx
Blue Sun Biodiesel
Catchlight Energy
Ceres
Chevron
Cobalt Biofuels
ConocoPhillips
Dow Chemical
DuPont
Ecopetrol-ICP
Flad Architects
General Motors
Gevo
Kimberly-Clark
Korth O'Neil Engineering
LiveFuels
LS9
Mascoma
OPX Bioproducts
PureVision Technology
Range Fuels
San Juan Bioenergy
Shell Global Solutions
Solix Biofuels
Suncor
Sundrop Fuels
Symbios Technologies
UOP
Valero
W.R. Grace & CO

Contact Information

FOR MORE INFORMATION, PLEASE CONTACT:
Frannie Ray-Earle, Center Coordinator
Colorado Center for Biorefining and Biofuels
Department of Chemical & Biological Engineering,
University of Colorado, Boulder, CO 80309-0424

c2b2@colorado.edu
303-492-7736
http://www.c2b2web.org

C2B2

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).

Congratulations C2B2 Researchers: Recipients of National Funding Awards

TITLE: ***Identification of Genes That Control Biomass Production Using Rice as a Model System***
INVESTIGATORS: Jan E. Leach, Daniel R. Bush, John McKay, and Hei Leung (IRRI)
INSTITUTION: Colorado State University and International Rice Research Institute (IRRI, Philippines)
SUMMARY: Long term goal is to provide the applied biomass research community and industry with information to allow exploitation of the genes and pathways relevant to biomass accumulation in grasses. Despite historic selection away from biomass production for food-production purposes, rice is used as a genetic model to identify genes necessary for high biomass productivity in candidate biomass plants (switchgrass, Miscanthus).
AGENCIES: The Department of Energy's (DOE) Office of Biological and Environmental Research and the U.S. Department of Agriculture (USDA) Cooperative State Research, Education, and Extension Service National Research Initiative.
AMOUNT and DURATION: $1,500,000 over 3 years
WEB-SITE: http://genomicsgtl.energy.gov/research/DOEUSDA/abstracts/2008leach_ abstract.shtml

TITLE: ***IGERT Program in Multidisciplinary Approaches to Sustainable Bioenergy***
INVESTIGATORS: Kenneth F. Reardon, Jan E. Leach, Daniel R. Bush, Keith Paustian
INSTITUTION: Colorado State University
SUMMARY: The goal of the MASB program is to prepare interdisciplinary PhD graduates with a broad understanding of the technical challenges facing the emerging biofuels industry.
AGENCY: National Science Foundation
AMOUNT and DURATION: $2,932,264 from 7/15/2008-7/14/2013
WEB-SITE: http://bioenergy-IGERT.colostate.edu

TITLE: ***Surface Studies of Multifunctional Oxygenates on Metal Surfaces***
INVESTIGATORS: Will Medlin
INSTITUTION: University of Colorado
SUMMARY: Studying methods for tailoring the surfaces of metal catalysts to improve selectivity in conversions of biorefining intermediates such as polyols and acids.
AGENCY: National Science Foundation
AMOUNT and DURATION: $300,000 from 09/01/08-08/31/11