Energy Biosciences Institute

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Berkeley graduate student Zack Baer in fermentation room

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DIESEL CONVERSION STORY SHOWCASES EBI'S CHARACTER

If the Energy Biosciences Institute was looking for a model to illustrate just how an academic-industry collaboration is supposed to work, then they found one in November. In a story that spanned the globe and received attention in print and broadcast media, EBI scientists discovered that a long-abandoned fermentation process once used to turn starch into explosives can be used to produce renewable diesel fuel.

Behind the news was a collegial system that showed the potential value of a program that partners university basic research with commercial business know-how. It also demonstrated the success of interdisciplinary research, a foundation upon which the EBI was formed.

EBI Principal Investigator and UC Berkeley Chemistry Professor Dean Toste had come up with catalysts that could use acetone and ethanol to make heavier molecules, but he didn't know if this might be useful. During EBI management's review of the Toste program on new catalysts, BP chemical engineer Paul Willems – EBI's associate director – suggested that Toste's method might be applied to an old process used to produce acetane, butanol and ethanol (ABE).

"I felt this might not only lead to a new route for diesel molecules," Willems recalled, "but it also might revive the old ABE process as attractive and a good outlet for the entire product slate. Historically,

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THE EBI AT 5: CHRIS SOMERVILLE REFLECTS

Five years ago, the Energy Biosciences Institute was inaugurated with a bold agenda that included an exploration of the ways that modern biology can be applied to energy problems, utilizing a multidisciplinary research model. The targets included next-generation biofuels and research that could remove roadblocks to making lignocellulosic biofuels, a major contributor to the nation's energy future. Director Chris Somerville vowed to make it a bioenergy think tank, funding efforts to, among other things, find and develop the best feedstocks, improve enzymes needed to break them down, engineer better fermenting microbes, and critically evaluate the effects of a push to turn plants into fuel on the environment and the food supply.

Today, the EBI has acquired an international reputation and a spanking new home at UC Berkeley, peopled by researchers from many disciplines who are addressing many of these areas. Satellite research centers are thriving at Berkeley Lab and the University of Illinois at Urbana-Champaign, which has a dedicated 320-acre farm.

At the halfway point in its 10-year, $350 million commitment to the academic partners from BP, Chris Somerville spoke with UC Berkeley science writer Bob Sanders and reflected on EBI's past and potentially exciting future and the prospects for biofuels in today's post-recession world.

Q: What have been the most important contributions of the EBI in the last 5 years?

The EBI has become a leading center in biofuels in the world, and many of the faculty are leading people in the world in their field. We have a new building so that we're finally able to get many of the EBI labs into a single very collaborative and interactive environment.

We have published almost 500 papers and made lots of discoveries. We have solved some major problems and have opened up completely new opportunities in the field of biofuels. One of these was the development of modified yeast strains that can simultaneously use 6-carbon and 5-carbon sugars -- yeast doesn't do that normally. Because biomass is a mixture of 5- and 6-carbon sugars, it is really important to be able to simultaneously utilize those at the same rate so we wouldn't have to run two processes. That came out of work on the fungus Neurospora by Louise Glass and Jamie Cate at Berkeley and from yeast engineering by Yong-Su Jin and Huimin Zhao at Illinois.

A lot of our papers are broadly based, because we have a multidisciplinary view. We have economists talking with chemical engineers, life cycle engineers talking with biologists and ecologists. We like to think that we are developing a literature that has a holistic view. We also have a lot of interactions with industry because we have a team of BP process engineers in the building. They participate in some of the discussions and help us understand the issues, bring us news from the industry, and facilitate interaction with industry so that we understand real-world problems.

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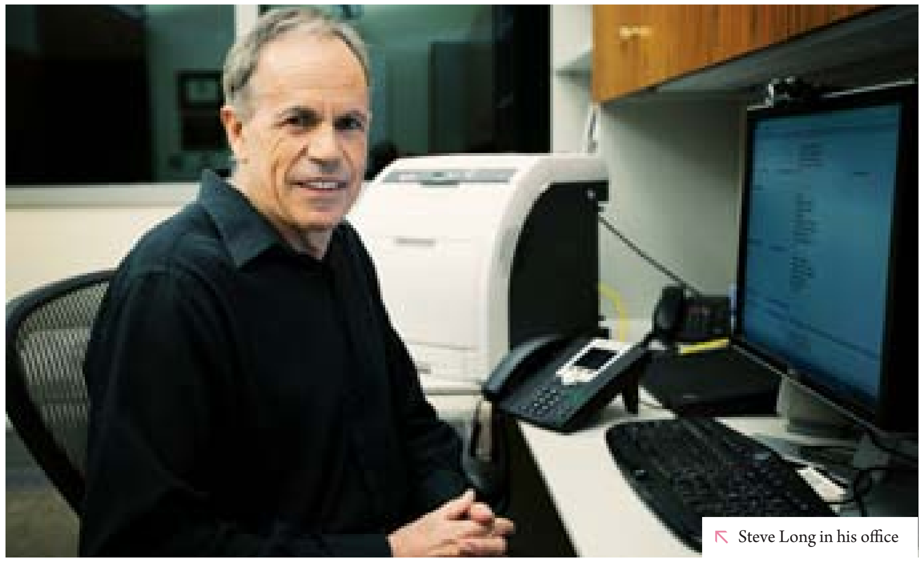
DEPUTY DIRECTOR LONG: 'EBI SECOND-TO-NONE IN ENERGY BIOSCIENCES'



Steve Long in his office

When Steve Long announced his resignation as Deputy Director of the Energy Biosciences Institute in November, he confessed to having "mixed feelings;" sad to be stepping down, excited about his new opportunities in crop photosynthesis research.

The feelings were much clearer, however, as he reflected upon the work of the EBI over his five-year tenure heading institute operations in Illinois.

"What has struck me most about the EBI, a unique experience in my 40 years as an academic, has been the commitment to success that you have all made – whether you are support staff, faculty, post-doctoral fellows and graduate students," he said in his announcement to all EBI employees. "Your hard work, innovation, commitment and willingness to build effective bridges has made the EBI second-to-none in the world of energy biosciences."

He also told everyone that he's not going anywhere. He will continue as program and project leader with the EBI in Illinois, and "will be pleased to provide advice, and help, where I may. I have enjoyed my tenure as Deputy Director very much, and I appreciate having had the opportunity to work with all of you. I am equally grateful to Chris Somerville and the (Research Vice Chancellor's Office) at Berkeley for including Illinois and myself as co-PI to the original application to BP, and for their support throughout."

EBI Director Somerville noted Long's impact. "Steve was one of the architects of the EBI, and much of the success of the organization derives from his vision," Somerville said. "The EBI has always been presented with many more interesting ideas for research projects than we have been able to support. Steve brought both wisdom and broad knowledge of the bioenergy sector to the difficult task of prioritizing funding decisions."

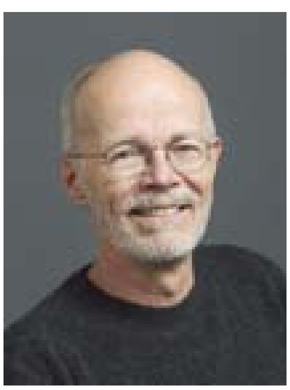
"I will miss seeing the day-to-day details behind the continued success of the Institute," Long said, "but I am looking forward to devoting more time to my research interests and addressing the important new opportunities that have arisen."

He noted that the new research efforts he wishes to pursue "are not compatible with also discharging the very important and significant duties of the Deputy Director." Long also said his decision was reached over several months and had nothing to do with BP's recent shift in direction for cellulosic biofuels programs.

"We are at the halfway point of this initial 10-year award," he added. "The EBI is well established and so I see this as an appropriate time for such a transition."

The Governance Board of the EBI will make the decision on who the next Deputy Director will be, and until then, Long will continue in that capacity.

FUNGAL RESEARCHER TAYLOR HITS CITATION MARK



A scientific publication by a team of UC Berkeley researchers from the laboratory of John Taylor, professor of plant and microbial biology and an EBI principal investigator, hit a rare benchmark in September when it was cited for the 10,000th time, according to Google Scholar. The publication, a chapter called "Amplification and Direct Sequencing of Fungal Ribosomal RNA Genes for Phylogenetics," appeared in the 1990 book *PCR Protocols: A Guide to Methods and Applications*.

Most scientific papers are cited just a few times, but seldom 100 times, and rarely a few thousand. The papers that earned Nobel prizes for UC Berkeley physicists Saul Perlmutter and George Smoot, for example, have been cited 8,882 and 2,260 times, respectively, according to Google Scholar.

"We described how to quickly and easily sequence a region of DNA from fungi that identifies the fungus and places the fungus in the Tree of Life," Taylor said. "This simple tool revolutionized two fields: fungal ecology and fungal phylogenetics, the process that builds the Tree of Life. The global effort to 'barcode' all of life -- that is, to catalog every organism using a DNA signature -- has adopted our protocol for fungi, and efforts are afoot to do the same for plants."

His co-authors of the chapter included Tom White of Cetus Corp., UC Berkeley professor Tom Bruns (also an EBI investigator), and Steve Lee of San Jose State.

Taylor and Bruns are currently working on the EBI project "Thermophilic Filamentous Fungi and Yeasts from Compost and Sugarcane," and previously completed work on another, "Fungi and Deconstruction of Lignin and Other Components of Miscanthus Cell Walls."

BP's Jennings demonstration biofuels plant in Louisiana

BP DROPS REFINERY PLANS; WILL CONCENTRATE ON TECHNOLOGY R&D

BP announced in November that it cancelled its plans to build a commercial-scale cellulosic ethanol plant in Highlands County, Florida and will instead refocus its U.S. biofuels strategy on research and development as well as licensing its industry-leading biofuels technology.

That technology search includes the work being conducted at the EBI, as well as at both BP's San Diego Global Technology Center and its Jennings demonstration plant.

In a message sent to all EBI employees, the EBI's directors said, "BP is exploring alternative ways to commercialize the technology. This could be through licensing or Joint Venture arrangements or through implementations in Brazil using bagasse as the raw material."

Chris Somerville, Steve Long and Paul Willems, in their joint statement, said, "It will take EBI management, the EBI Executive Committee and the EBI Governance Board some time to understand how the EBI can best be positioned to continue to provide value to the sponsor. It is worth noting, in this respect, that BP is one of the largest biofuel companies in the world and has announced intentions to significantly expand this aspect of its business. The fact that BP will continue to operate the Jennings plant and the center in San Diego reflects a continuing interest in advanced biofuels technology."

Their message continued, "As most EBI investigators know, the technology for making fuels from lignocellulose still needs a lot of improvement to bring capital and operating costs down in order to make investments in commercial production of lignocellulosic fuels attractive. Therefore, the lignocellulosic biofuels research portfolio of the EBI remains highly relevant to the broad goal of creating a next-generation biofuels industry.

"It is also worth noting that EBI has been positioned from the outset as having a focus on the broad topic of bioenergy, not just lignocellulosic biofuels."

BP originally announced plans to build the Florida facility in 2008 with the intention of turning thousands of acres of energy crops into 36 million gallons per year of cellulosic ethanol. While ending its pursuit of commercial-scale cellulosic ethanol production in the U.S., BP continues to invest in and operate its world-class biofuels research facilities and to further develop next-generation cellulosic biofuel technologies and license them for commercial use around the world.

Globally, BP is a leading investor in commercial biofuels production. The company has completed construction of its joint venture 110 million gallon per year ethanol plant in Hull, England, which is expected to come online later this year. In Brazil, BP took ownership of three sugarcane ethanol mills located in the Goiás and Minas Gerais states of Brazil in 2011 and is currently expanding production there. In addition, BP is developing advanced biofuel technology via its joint venture investment in biobutanol company Butamax.

MICHIGAN STATE HONORS SOMERVILLE WITH HONORARY SCIENCE DOCTORATE

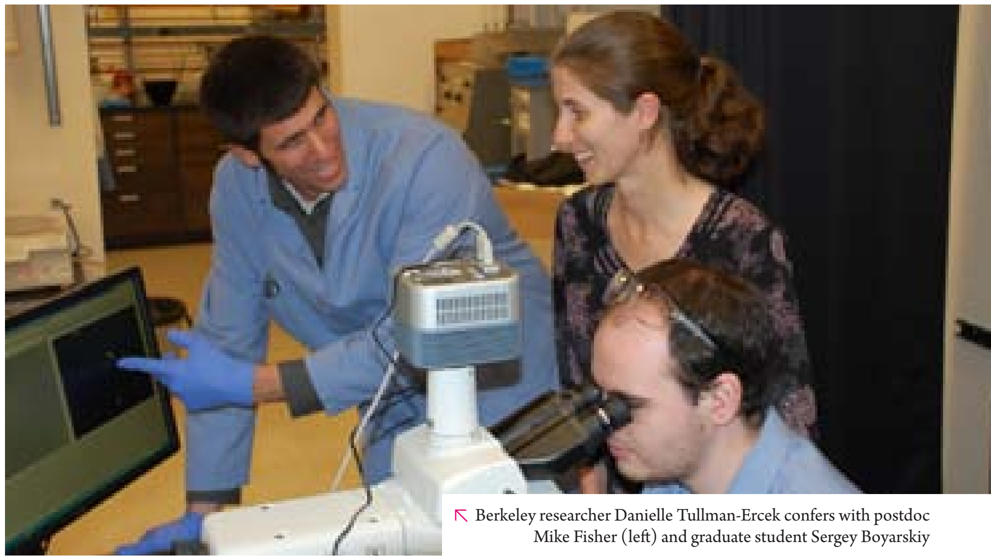
EBI Director Chris Somerville can add one more honor to his extensive resume – Honorary Doctorate of Science from Michigan State University.

He was to receive the award at Fall Commencement exercises in East Lansing on Saturday, Dec. 15.

Somerville was honored for his internationally recognized work on the characterization of photosynthesis, membrane biology, cell wall synthesis, Arabidopsis as a model species for plant molecular genetics, plant genomics, lipid metabolism, and polysaccharide synthesis. He was also cited for moving the world's energy community into a new era.

He was on the faculty at Michigan State from 1982-93, as a member of the MSU-DOE Plant Research Laboratory and as a professor in the former Department of Biology and Plant Pathology. In those capacities, he helped shape MSU's plant research program.

AGAVE, INVASIVE SPECIES, BIODIESEL AMONG 2012 STUDY TARGETS



Berkeley researcher Danielle Tullman-Ercek confers with postdoc Mike Fisher (left) and graduate student Sergey Boyarskiy

As the Energy Biosciences Institute turns the corner toward its second five years, a look back at research begun in 2012 reflects new looks at potential feedstock crops, biodiesel precursors, crop invasiveness, investment incentives for the refining industry, and stillage (stalks and stover) from corn and energy cane.

Here are the EBI projects that were begun or, in some cases, refocused and continued, in the year 2012:

AGAVE AS A FEEDSTOCK CROP IN THE SOUTHWESTERN U.S.

EBI Feedstock Analyst Sarah Davis and Deputy Director Steve Long of Illinois have been studying Agave spp. as a potential bioenergy crop that can be grown in semi-arid regions without competing with agricultural lands used for food crops. Because agave plants have high water use efficiency, relatively low lignin, and potentially high yields, this genus has promise as a bioenergy crop that requires little inputs. A field trial of three species has been established in Maricopa, AZ, for study over the next five years.

DIVERSIFYING POTENTIAL CELLULOSIC PERENNIAL FEEDSTOCKS WITH PRAIRIE CORDGRASS

D. K. Lee at the University of Illinois has been studying this crop, a native warm-season grass that grows well on poorly drained and/or salt-affected soils. Having already established a collection of native germplasms, Lee and his team are now determining the best genetic resources for developing improved populations and cultivars across multiple locations and growing seasons, and the best planting systems and management practices for prairie cordgrass production in land not suitable for traditional row crops.

BIOMASS FEEDSTOCK LEGAL AND REGULATORY CHALLENGES: INVASIVE SPECIES REGULATION, BIOTECHNOLOGY APPROVALS AND GERMPLASM CONTROL

Agriculture law specialist Bryan Endres of Illinois is analyzing the legal and regulatory structures that govern invasive species, genetically engineered biomass feedstocks and contractual mechanisms to manage intellectual property rights in germplasm. Invasive species rules influence biotechnology regulation, as well as potential private law liability concerns associated with genetically modified plants. The project is developing a science-based decision-making framework to avoid or mitigate these risks in the bioenergy field.

DEVELOPMENT OF AN OLEAGINOUS YEAST MODEL SYSTEM

Berkeley's Adam Arkin, principal investigator for the EBI's Microbial Characterization Facility, is now studying several oleaginous yeast species to compare their genetic tractability and lipid productivity. The team's goal is to identify the best strain for carrying out detailed functional genomic and metabolic engineering studies to make fatty acid-derived diesel-like fuels in oleaginous yeast.

ENGINEERING FILAMENTOUS FUNGI FOR INCREASED LIPID PRODUCTION AND SECRETION

Berkeley scientist Doug Clark, currently managing the EBI's lignocellulosic bioconversion program, is also focusing on the complex organics required to produce lipids – precursors to biodiesel development – as options to oilseed crop sources. Using a cellulolytic filamentous fungus like *Neurospora crassa* to produce and secrete lipids, Clark and his team are developing an approach for the redesign of any cellulolytic fungus to achieve maximal lipid production and secretion from lignocellulosic biomass.

ENGINEERING OLEAGINOUS YEAST FOR LARGE-SCALE BIODIESEL PRODUCTION

One of Illinois chemical engineer Christopher Rao's EBI projects, this one focuses on reducing the oxygen demand during the production of biodiesel precursors in yeast. Oleaginous yeast are promising organisms for the production of biodiesel, but their applicability for large-scale production is limited because they require oxygen to produce lipids. Rao is working to reduce the oxygen demand in one yeast strain and to produce diesel-like molecules in *Saccharomyces cerevisiae*.

ENGINEERING THERMOPHILES FOR BIOFUEL PRODUCTION

Another Rao project, it aims to develop a thermophilic bacterium for the production of lignocellulosic biofuels. Having already developed a suite of genetic tools for engineering the thermophiles from the genus Geobacillus, Rao is further developing these tools as well as applying them to develop Geobacillus for fuel and enzyme productions.

ALTERNATIVE PROGRAMS TO INCENTIVIZE INVESTMENT IN U.S. CELLULOSIC BIOFUEL REFINING INFRASTRUCTURE

New to the EBI, Illinois professor Nicholas Paulson is looking at economic, legal, and/or political incentives that will be required to move cellulosic fuel production toward commercialization. Among his tasks are analyzing loan guarantee programs, designing innovative insurance programs, and evaluating the potential for private market derivatives which would

D. K. Lee at the University of Illinois

provide potential refiners with funding sources and risk management tools.

SUSTAINABILITY OF WOODY BIOFUEL FEEDSTOCKS

Illinois researcher Andrew Leakey is looking at short-rotation coppice forestry – in which tree stands are cut back and re-grown – as an option for second-generation bioenergy production. By studying existing forestry sites in Wisconsin, New York and North Carolina, he is measuring the impact of the coppice system on ecosystem services, such as carbon sequestration and water cycling.

SELECTION OF HIGH-YIELDING ENERGY CANE CLONES FROM TRANSGRESSIVE SEGREGATING POPULATIONS

Illinois plant biologist Ray Ming has been working on energy cane breeding techniques that could accelerate cane breeding, shorten the typical breeding cycle of 13 years in energy cane and sugarcane breeding programs, and maximize the biomass yield from new germplasm generated from interspecific recombination. He is conducting yield trials of the plant segregants in Hawaii and Florida, and his team continues to screen additional interspecific species populations for high-biomass-yield clones.

MESOPHILIC AND THERMOPHILIC BIOCONVERSION OF STILLAGE DERIVED FROM LIGNOCELLULOSIC BIOMASS-TO-ETHANOL FERMENTATION TO METHANE

Illinois microbiologist Roderick Mackie is looking at the composition of corn stover and energy cane, two potential sources of lignocellulosic stillage residues from crops, as they go through anaerobic digestion and fermentation. The data collected will help assess the potential of these sources for efficient hydrolysis and processing to fuel in the presence of microbial digesters.

MESOPOROUS CARBON NANOPARTICLES

Alexander Katz, a Berkeley chemist who has already produced results in the EBI project on enzyme-inspired catalysts, now is focusing on enhancing biomass depolymerization with the use of reactive materials consisting of mesoporous carbons. Using Miscanthus as a biomass source, he is employing practical process conditions to develop an overarching understanding of the mechanisms by which mesoporous carbons stimulate conversion processes and enhance biomass deconstruction.

CHARACTERIZATION AND ENGINEERING OF THE TPO TRANSPORTERS FOR BIOFUEL SECRETION IN SACCHAROMYCES CEREVISIAE

Having studied secretion pumps for fuel-producing bacteria, Berkeley chemical engineer Danielle Tullman-Ercek is now focused on a small-molecule secretion pump that is engineered to enable the transport of the fuels of interest at high yield in yeast. This biofuel efflux machinery is focused on alcohol and fatty acid substrates.

BIOFUEL LAW AND REGULATION: FEDERAL/STATE LAW AND POLICY

What was once an EBI program on law and regulation now has two projects. In this one, headed by law professor Jay Kesan at Illinois, prior studies of the legal and regulatory regimes, frameworks, policies, and institutions at the federal and state level affecting the commercialization of second-generation biofuels will lead to proposed well-reasoned regulatory reforms.

BIOFUELS LAW AND REGULATION: SYSTEM SUSTAINABILITY

This second project, directed by Illinois assistant professor Jody Endres, applies systems thinking in its quest for new policy approaches to more timely and effective commercialization of biofuels and bioenergy. It focuses on the myriad individual components of systems-level challenges and solutions both in the U.S. and abroad, such as policies that address the food-fuel resource scarcity debate, biofuels sustainability standard development, and incorporation of sustainability principles into the supply chain.

EBI FUNDS EIGHT PROJECTS, TWO FELLOWSHIPS TO BEGIN IN 2013

Eight projects and two fellowships have been funded by the Energy Biosciences Institute for work commencing in 2013. They include (with principal investigator names):

- "Nanostructured Polymer Membranes for Alcohol Separation and Hydrolysate Detoxification," Nitash Balsara, UC Berkeley
- "Analysis of Brazilian Deforestation," Maria Bowman, UC Berkeley
- "Practical Synthesis of Recyclable Cellulase-Bioconjugates," Matthew Francis, UC Berkeley
- "Adding Biofuel Feedstock Options to Regional Forest Product Market Models," Keith Gilless, UC Berkeley
- "Yeast-Produced Endolysins to Prevent Bacterial Infections of Ethanol Fermentations," Michael Miller, University of Illinois
- "Genome-Wide Association to Identify Genes for Biofuel-Relevant Phenotypes in Kluyveromyces marxianus and Issatchenkia," John Taylor, UC Berkeley
- "NMR as an Analytical Tool in Biofuel Research," David Wemmer
- "Socioeconomic Dimensions of Brazilian Land Use Governance" (Avery Cohn, UC Berkeley, Fellowship)
- "Politics of Sustainable Biofuels Policy" (Hannah Breetz, UC Berkeley, Fellowship)

All of the above investigators have been involved in previously funded projects within the EBI except for Michael Miller, assistant professor of nutritional sciences at Illinois, and Hannah Breetz, who is a recent political science Ph.D. graduate from MIT and will be working jointly with the EBI and the Goldman School of Public Policy.

THE EBI AT 5
(cont. from page 1)

Importantly, we have educated and graduated the first cadre of new students – by the end of this year, several hundred graduate students and post-docs -- who are going out and getting jobs in not only the biofuels industry but in industry and academia more broadly. EBI students and post-docs frequently come to my office as they are leaving for a new position to talk about how their view of research has been expanded by the interdisciplinary interactions within the EBI. I have found this aspect of the EBI mission to be the most satisfying.

Q: How does this fit with the original goals of the EBI?

I think that at the outset there was an impression that because we are industry-supported, we would be focused on the next incremental thing. That is just so far from where we are. We are mostly interested in game-changing innovation.

The Neurospora story, where we found a solution to the problem of using all the sugars, is an iconic example of this. It was an important problem where we made progress thanks to the collaboration of all three organizations -- Berkeley, BP and Illinois -- and where a whole new opportunity opened up for us. The discovery came from blue-sky work in which we were simply asking a very basic question: How does the fungus Neurospora grow on biomass?

In the course of addressing that very basic question, John Galazka, a student in the Cate lab, found the gene that allowed uptake of the disaccharide cellobiose, which is composed of two glucose molecules. A BP engineer, Xiaomin Yang, recognized it might allow industrial yeast that are used to produce ethanol to utilize glucose in the form of cellobiose and xylose. Within a few days of him coming up with the idea, we transferred the genes from Berkeley to Illinois, and colleagues there put it into the yeast, and sure enough the yeast would then use both C-6 and C-5 sugars simultaneously.

The next thing that happened was that the discovery of the co-utilization capability triggered a rethinking of the overall process. Paul Willems, a BP engineer who serves as Associate Director of the EBI, has from the very outset been uncomfortable with the concept that biofuels are currently made as batch processes. In brief, in a batch process a big tank is filled with sugar solution, an organism is added and it ferments for a while and then you pump it all out. While you are emptying the tank and cleaning it up, it's unused capital, which increases the costs of production. Also, a batch process only operates optimally for a brief period of time, because during the fermentation many things are changing (eg., sugars are being consumed, fuel is accumulating). Paul realized that the ability to utilize the two major sugars simultaneously removed one of the barriers to using a continuous process instead of a batch process.

Once we realized that we had solved one of the problems in going from a batch process toward a continuous process, the subject of a continuous process became a major priority, and we are really working now to solve other problems associated with a continuous process. In terms of our big goal of reducing the overall costs of biofuels below the cost of petroleum, if we can make it run continuously, I think it is likely we can beat the price of petroleum without subsidies.

Q: Give us an example of some other innovative work that has come out of the EBI.

Because ethanol cannot be used as a diesel substitute, we have an institute goal of finding ways to make diesel from lignocellulosic biomass. Chemical engineering professor Alex Bell, for example, is developing a series of chemical steps that convert sugars to diesel directly (i.e., without fermentation). Alternatively, chemistry professor Dean Toste has found a catalyst and a system for condensing the products of Clostridium fermentation, called the ABE process, into diesel-like molecules. Chemical engineers Doug Clark and Harvey Blanch have devised an innovative method for separating the ABE products from the fermentation broth, and chemical engineer Nitash Balsara is working on membranes that allow us to separate the ABE products out of the fermentation without doing some sort of distillation. Thus, as with the sugar co-fermentation story, we have parallel work on different subjects that has converged.

Dean's work, with Doug Clark and Harvey Blanch and collaborators, was just published in *Nature*. I think that their paper is a particularly nice example of a multidisciplinary approach because it brings together biology, chemistry, and chemical engineering to create a possible route to a goal that has not been achieved by a single discipline. And, of course, some very nice basic science was involved in getting to a possible solution.

Q: How did these come about?

When BP decided to locate the institute at Berkeley, it wasn't because Berkeley was a leading center of biofuels research. In fact there were many other centers that got started long before Berkeley. But they chose Berkeley because it is a very distinguished school with a lot of excellent and enthusiastic people whom we believed we could recruit to tackle problems in the area of biofuels. Toste, Cate, Glass and Balsara are perfect examples – none of them had worked in any fields related to biofuels or fuels. EBI put in place some processes that helped educate them about the problems in the field, helped them identify topics where their skills and knowledge could be brought to bear on important problems, gave them access to funding and technical support that reduced the time and effort required to work in the field, and facilitated some productive collaborations. Their successes in creating important breakthroughs in the field are very satisfying. I consider their accomplishments important examples of the power of encouraging and empowering really talented people to work on tough problems of societal relevance. More generally, I think the EBI has become a useful model of how the intellectual resources of major research universities can be brought to bear on big problems of societal relevance.

Because we are focused on long-term goals rather than incremental improvements, nothing that we have discovered is yet in commercial use, though some things are in commercial development.

Q: Since the EBI was launched in 2007, how has the national outlook for biofuels changed?

Ethanol is well established and a big success worldwide in terms of volume of production. At about 22 billion gallons a year, it's the largest bioproduct in the world. More generally, biomass-based energy, which includes biomass-to-power as well as biofuels, contributes about 35 times more energy than all solar in the U.S. One should not consider biofuels as some sort of fringe activity; it is the most rapidly growing component of the energy sector.

That said, in the United States ethanol means corn ethanol, and the demand for that is already saturated. Growth of the industry in the U.S. is now limited by our ability to increase the proportion of the fleet that can use more than 10 percent ethanol, which is the current federal mandate. The Environmental Protection Agency has been trying to do this by approving some cars for up to 15 percent ethanol. Increasing the number of E85 pumps would help, but less than 5 percent of the light duty vehicles in the U.S. are flex-fuel and can use E85. The auto industry needs to make every new car and light truck flex-fuel vehicles.

The other strategy is to actually make fuels that are not ethanol, but things much more like diesel and gasoline so they are compatible with current infrastructure and the vehicle fleet. So that is a major goal of the EBI, figuring out how to turn biomass into diesel and gasoline.

Q: One of your goals is to develop processes to convert more of the plant – the hard lignocellulose as well as the sugar – into fuel, such as ethanol: a process referred to as cellulosic. Yet BP recently decided not to open a cellulosic plant they had been developing in Florida. What does this say about the future of cellulosic?

My opinion is that because there is currently a lot of technical innovation still happening in this area, it is probably premature to build a biorefinery for production of lignocellulosic fuels. Academic work in the field has not yet converged to an optimal process. As I said, we think that such an optimized process will be continuous. When we get to a situation where academic studies have converged on the most efficient process and predict economic feasibility without subsidies, then it will be appropriate to start building biorefineries. Some companies appear to have started building lignocellulosic fuel biorefineries because they have adequate confidence in their own technologies, they want to capture possible business advantages of being early movers, and (because of) pressure from the government to get on with it in order to preserve the subsidies that are currently available for advanced biofuels. I cannot evaluate the merit of these possible motivations. However, based on technical progress in the field, I remain very optimistic that we will eventually have a very large industry based on lignocellulose feedstocks.

Q: What about the large portion of your research portfolio in economic, social and environmental impact.

About 20 percent of our research portfolio is in these fields. One example of the kind of research we are supporting is a large long-term sustainability experiment we started at the very beginning of the EBI comparing prospective energy crops with conventional crops and with the native ecosystem of prairie grass on a 320-acre farm at the University of Illinois. Professors Evan DeLucia, Mark David, Carl Bernacchi and collaborators monitor all the gases emitted, including greenhouse gases like nitrous oxide, methane and carbon dioxide; the mineral content of water runoff; soil carbon; and the plant and animal biodiversity. It is our largest single research expenditure. At the end of the 10 years we are going to have a unique dataset where we literally are going to be able to understand all the inputs and outputs at a practical scale, and know what the environmental consequences are of growing various prospective crops such as miscanthus and switchgrass. I really like that experiment because it is an area of research that is very hard to support with public funding, so it takes advantage of the long-term support for EBI from BP. Also, in contrast to a lot of current academic work that is model-based and, therefore, very susceptible to errors based on which assumptions are used, we are obtaining real data.

Q: Has that had any impact on the balance of crops now used to create biofuels? It is still predominantly corn.

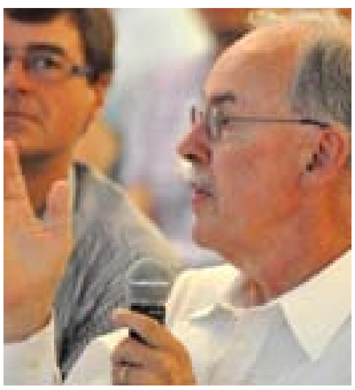
In the U.S. it is still almost entirely corn. However, we believe that most or all biofuels will eventually be made from perennial plants grown specifically for energy, and from various types of residual materials and waste. In the EBI, we are doing the work necessary before we plant very large amounts of a perennial crop like switchgrass. We of course have been looking for new crops. Our scientists interact with 30 botanical gardens which have been sending us candidate biomass species which we grow in plots on the farm and at 16 other locations around the U.S. That aspect of our work has directed our interest toward several native species that perform very well, prairie cordgrass and a nitrogen fixing tree, black locust. Both species are very widely distributed across the U.S. and are quite productive on marginal land. The prairie cordgrass is very salt-tolerant so we are testing it on land that has fallen out of agricultural production because of soil salinization. D.K Lee, one of our investigators at the University of Illinois, collected plants from all over the U.S. and has identified types that perform very well in different climatic zones and soil types. I think it will be a good choice for biomass production in many regions of the country.

We are also interested in the possibility of utilizing the large amounts of trees that were planted to produce pulp and paper but which may be available for other uses because of the decline of the industry in the U.S.

Q: Are there some myths about biofuels you would like to dispel?

Biofuels seem to have fallen out of favor in the past five years. The problem with that perception is that everything is lumped together as biofuel even though corn ethanol and sugarcane ethanol and lignocellulosic fuels are very different things. More than 99 percent of the public discourse about biofuels in the U.S. is about corn ethanol and doesn't even reach anything the EBI works on. I think we need to get a more refined language for discussing this subject. When I talk about cellulosic fuels or lignocellulosic fuels instead of corn ethanol, environmental groups and organizations like the Union of Concerned Scientists are very positive.

Another myth is that somehow the amount of land available is in short supply. That is so untrue. The fact is that we pay farmers not to farm more than 30 million acres in the U.S., not to mention the unused land that does not qualify for subsidies. There is a tremendous amount of land available.



We had a study inside the EBI which mirrored a study done by a group of ecologists at Stanford, in which it was estimated that around the world there are more than 1.3 billion acres of land that had been farmed and subsequently abandoned -- more than half the landmass of the U.S. – that could be used to grow biofuel feedstocks. Those acres are particularly interesting in the context of biofuel production because the environmental costs of converting native land to agriculture (e.g., loss of biodiversity, carbon emissions) have already been paid during the original conversion. Additionally, I would estimate more than 3 billion semiarid acres that are not used for agriculture might be suitable for growing drought-tolerant native plants such as *Agave americana* that require much less water than the plants used for agriculture.

Q: What happens in 5 years, when the EBI funding runs out?

My personal belief is that EBI will continue beyond 2017, with funding from BP and/or someone else. I personally think we are doing something here that is an interesting and important model for a new way of doing things in the university. While a great university like Berkeley has knowledge in just about everything, sometimes, to address big societal problems, you have got to get lots of experts working together. What I think is unique about an institute like the EBI is that we have been empowered to bring lots of expertise in different topics together to work on a societal problem -- what can we do to the energy sector from the perspective of biology to advance some of our societal goals, such as low carbon energy and sustainability?

When we formed the EBI, Steve Chu talked about how things were done at Bell Labs, so we tried to emulate that model as far as possible in this context. One of the things about Bell that we have replicated is to reduce barriers to interaction between different disciplines. We have open hallways connecting all the labs, and there is lots of interaction. We put groups with different expertise beside each other in the same space. And we have a leadership group that brokers interactions between the different groups. Because the leadership team has an overview of all the research that is under way, whenever we see a connection between different aspects of research, we bring people together.

It is a privilege to lead such an organization. I really hope that we are setting a good example of how we can marshal a great university like Berkeley to address other societal problems.

There was concern at the outset that somehow EBI would be at cross-purposes with the university because of the reliance on industry support. But we are not. We are educating a unique cadre of students, we are creating and disseminating information in the field, and we are minimizing the delay between discovery and application to societal problems because of our close relationship with the sponsor. I think that is a really key thing, to actually be doing something about the climate and energy problems beyond just handwringing.

EBI PARTICIPATES IN RESEARCH THAT IMPROVES XYLAN EXTRACTION

Researchers have identified a gene in rice plants whose suppression improves both the extraction of xylan and the overall release of the sugars needed to make biofuels. The work, featured in the *Proceedings of the National Academy of Sciences*, was conducted at the Joint Bioenergy Institute (JBEI) in Emeryville, with a nice assist from the Energy Biosciences Institute.

The newly identified gene – dubbed XAX1 – acts to make xylan less extractable from plant cell walls. JBEI researchers, working with a mutant variety of rice plant, found that not only was xylan more extractable, but saccharification -- the breakdown of carbohydrates into releasable sugars -- also improved by better than 60 percent.

After cellulose, xylan is the most abundant biomass material on Earth and therefore represents an enormous potential source of stored solar energy for the production of advance biofuels. A major roadblock, however, has been extracting xylan from plant cell walls.

"In identifying XAX1 as a xylan biosynthetic protein, the first enzyme known to be specific to grass xylan synthesis, we've shown that xylan can be modified so as to increase saccharification," says Henrik Scheller of JBEI, who also holds an appointment with Lawrence Berkeley National Laboratory. "Our findings provide us with new insights into xylan synthesis and how xylan substitutions may be modified for increased biofuel generation."

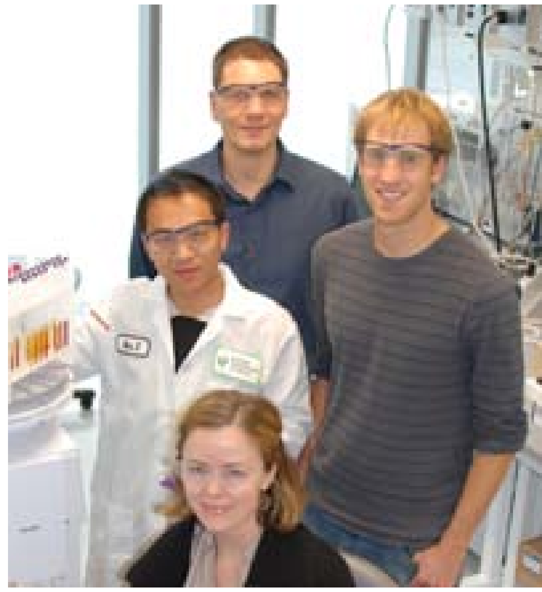
Taking advantage of the outstanding facilities and expertise in the EBI, UC Berkeley graduate student Alex Schultink and postdoc Kun Cheng, under the guidance of associate professor and EBI principal investigator Markus Pauly, analyzed the unusual xylan fragment found in the XAX1 mutant. They provided unambiguous evidence that the rice-mutant lacked a specific sugar portion at a specific position.

The paper's first author, Dawn Chiniquy, is now a postdoc in Shauna Somerville's EBI laboratory.

Scheller is a co-author of a paper, and Pamela Ronald of UC Davis and JBEI is the corresponding author. It can be read here: ***http://www.pnas.org/content/109/42/17117.full?sid=70062591-577f-469a-88da-09373eb5dca8***

Xylan, like cellulose, is a major component of plant cell walls that serves as a valuable source of human and animal nutrition. Despite its importance, few of the enzymes that can synthesize xylan-type polysaccharides have been identified. It is believed that xylan plays an essential structural role in plant cell walls through cross-linking interactions with cellulose and other cell wall components. Xylan is of particular interest for the improvement of feedstocks for the generation of cellulosic biofuels.

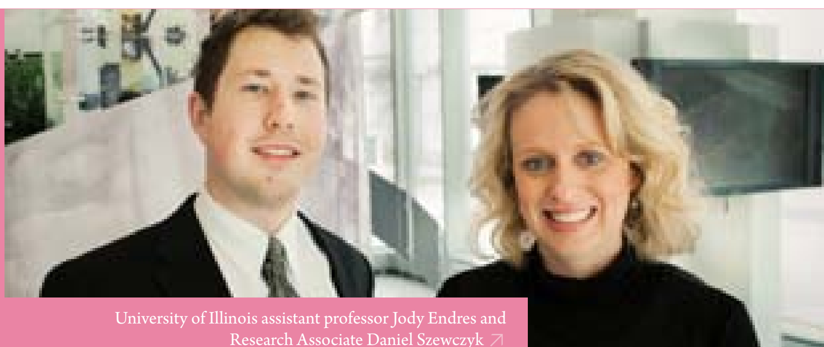
To find genes important for grass xylan biosynthesis, Ronald, Scheller and their co-authors focused on the GT61 family of glycosyltransferases. GT61 enzymes have been identified through bioinformatics as being expanded in grasses and containing grass-specific subgroups. Working with rice plants, a standard plant model for studying grasses, they conducted a reverse genetics screen of 14 genes with insertional rice mutants that are highly expressed members of the GT61 family. This led them to the identification of the mutant plant that resulted in the function of the XAX1 being knocked out.



Clockwise from bottom: Dawn Chiniquy, Kun Cheng, Markus Pauly, and Alex Schultink ↗

"We can apply the same principle used to make rice plants more easily saccharified to bioenergy crops," Scheller says. "With the ability to modify cross-linking between xylan and lignin by targeting a glycosyltransferase, we also now have a potentially important new biotechnological tool for grass biofuel feedstocks."

– Lynn Yarris



University of Illinois assistant professor Jody Endres and Research Associate Daniel Szewczyk ↗

BIOFUEL SUPPORTERS NEED METRICS TO PROVE VALUE IN 'GREEN ECONOMY'

Between the controversies surrounding renewable energy policies like the U.S. Renewable Fuel Standard (RFS) and international debates like "food vs. fuel," a biofuel future of funding support may depend upon the industry's ability to prove its value beyond economic development. And, according to EBI researchers, therein lies the problem.

"Supporters' best hope in the battle for funding and biofuels' public image is perhaps the potential for creating a green economy in rural America," writes University of Illinois assistant professor Jody Endres and Research Associate Daniel Szewczyk. "The study of 'greenness,' as opposed to only generic economic development, is critical because 'greenness' distinguishes and justifies bioenergy sector subsidies in an extreme climate of budget austerity and political polarity."

They summarize their conclusions in a paper posted on Farmdoc Daily, a web-based publication of the Department of Agriculture and Consumer Economics at Illinois.

They point out that despite mandates and commitments to renewable fuels by governments on the basis of biofuels' environmental and social benefits, a backlash against the industry is mounting from myriad directions. Food security is a big issue. The rise of food and feed prices, which some blame on biofuels' use of food crops like corn, has exacerbated the arguments.

"Academia has failed to adequately develop a framework for evaluating what constitutes a 'green' economy, including by what metrics it should be measured," the authors write. "Efforts are beginning, however, largely in response to looming bioenergy compliance requirements that for the first time seek to measure the economic and social benefits of environmental improvements within the broader meaning of 'bio' fuels. Federal agencies also appear keen to develop social impact metrics that tie to environmental achievements for project funding decisions, thus driving demand by the private sector for standards that define their contributions to a 'green' economy."

The creation of accurate and legitimate "green economy" metrics also is increasing in importance due to legislation requiring federal agencies use of impact

Visitors enjoy a chilly October day on the Energy Farm, listening to scientists like Mir Zaman Hussain (right) at various tour stations

LEARNING WHAT'S DOING, AND GROWING, DOWN ON THE (ENERGY) FARM

Despite unseasonably blustery weather, which had many people shivering in their coats and clutching cups of coffee to keep their hands warm, attendance at the fourth annual EBI Energy Farm Open House in mid-October was strong.

Those who visited the 320-acre Urbana, IL outdoor plant laboratory to learn about the latest in bioenergy feedstock development included small farmers, companies developing energy crops, agribusiness consultants, members of the Illinois Farm Bureau, Department of Natural Resources, Illinois Extension program and National Park Service, reporters for various publications, and half a dozen University of Illinois students from Future Green Leaders, a campus club.

The Energy Farm provides space and resources for large-scale, field-based research on energy crop candidates. Scientists investigate which energy crops produce the most biomass and use the least resources in which climates; what cropping and processing methods work best; what threats, including insects or pathogens, those crops face; and how farmers can produce these crops as efficiently as possible.

During the open house, 18 visitor stations were scattered across the farm's acreage, and rack wagons made regular 10-minute circuits, carrying participants from display to display. Presentations ranged from identifying and controlling insect pests in energy crops and measuring the environmental impact of feedstock production, to comparative genetic studies of various feedstocks and efforts to measure carbon storage and water use of perennial and annual feedstocks.

At the sorghum plot, EBI principal investigator Pat Brown talked about sorghum's potential as a replacement or addition to Miscanthus. Sorghum, a close relative of corn, can be harvested using the same machinery and is very drought-tolerant. The plot held many varieties, which were undergoing genetic testing to determine which genes control traits relevant to bioenergy production.

At another plot, investigators studied the potential of native prairie grasses as feedstock. Identifying the best strains and cultivation practices will help integrate prairie grasses into the energy crop portfolio, they said.

At the pest management display, visitors saw insects that had infested various crops, and presenters discussed the control methods they had tested, which included periodic mowing, burning, and insecticides. They also studied individual plants of *Miscanthus x giganteus* to determine the effect of yellow sugarcane aphids on biomass production. A similar study was conducted in the greenhouse, and the results will be compared.

Presenters at another station compared Miscanthus fields with plots of corn, switchgrass and mixed prairie. They surveyed for birds and mammals and found that switchgrass monocultures provide almost as wildlife-friendly an environment as mixed prairie, but that Miscanthus, with wildlife numbers as low as in corn, does not promote vertebrate biodiversity.

Further into the Energy Farm, researcher Gary Kling talked to a dozen visitors about his group's experiments in woody crops, including poplar, willow and Chinese Wingnut, a cousin to the black walnut that likes wet soil and which he said could be grown on marginal lands. Woody crops have many positive features: they are fast growing and biomass production is high; they are not harvested every year, which reduces soil compaction and provides a better wildlife habitat; they can be selectively harvested if needed to augment the supply of biomass produced by perennials if growers experience a shortfall; and many sequester carbon effectively.

Another group discussed the sustainability of feedstock production by quantifying the amounts of carbon, nitrogen and water used or sequestered by Miscanthus, switchgrass, native prairie and a traditional corn-soybean-corn rotation. In addition, they study how soil microbes affect these processes. They reported that over the previous three years, Miscanthus used more soil water than corn, soybean or switchgrass, while switchgrass used as much water as corn but had a higher net uptake of carbon. The group also found that different soil microbial communities existed under different crops. Those under switchgrass and Miscanthus were more similar to one another than to corn. Their findings suggest that there are significant environmental benefits to replacing row crop agriculture with perennial grass feedstocks.

Visitors from all over the world have traveled to see the Energy Farm. For example, the day after the Open House, a delegation from the Swedish University of Agricultural Sciences visited, and last year 200 farmers from Argentina toured the farm.

– Deb Aronson

statements in project funding and rulemaking decisions. What's needed, they conclude, is the integration of environmental impacts into calculations of socio-economic benefits to communities, so that projects like biorefineries can be fairly evaluated.

That will be especially important since the USDA estimates that at least 527 biorefineries must be built in the U.S. to achieve renewable energy goals.

"No public or private bioenergy-specific standard currently achieves this integration," they state. "This includes answering such questions as: how do biorefineries build intellectual capacity within a community by attracting and retaining a green-educated workforce? How do cellulosic cropping systems improve water quality, which in turn may reduce water purification costs for municipalities? How can improved habitat for animals and birds increase tourism and recreation opportunities? Do practices that sequester carbon enhance the income of farmers, which in turn is spent within the community?"

Endres and Szewczyk work on the EBI project "Biofuels Law and Regulation: Systems Sustainability."

A SITE TO BEHOLD

EBI COMMUNICATIONS TEAM CREATES ELECTRONIC HOME THAT IS ATTRACTIVE, USER-FRIENDLY

Web developer Yoshi Kita and senior graphic designer Mirhee Lee in Illinois

As the EBI's Berkeley research teams were moving into their new homes in a new five-story facility this fall, another EBI "home" was being completed in cyberspace. The launch of the redesigned and reorganized institute web site in October marked the beginning of a new era of information-sharing and outreach to the world.

The website changes were implemented after a year-long analysis that featured user surveys and technical reviews. Communications staff at the University of Illinois at Urbana-Champaign provided the design and infrastructure, and their colleagues at the University of California, Berkeley, provided the content.

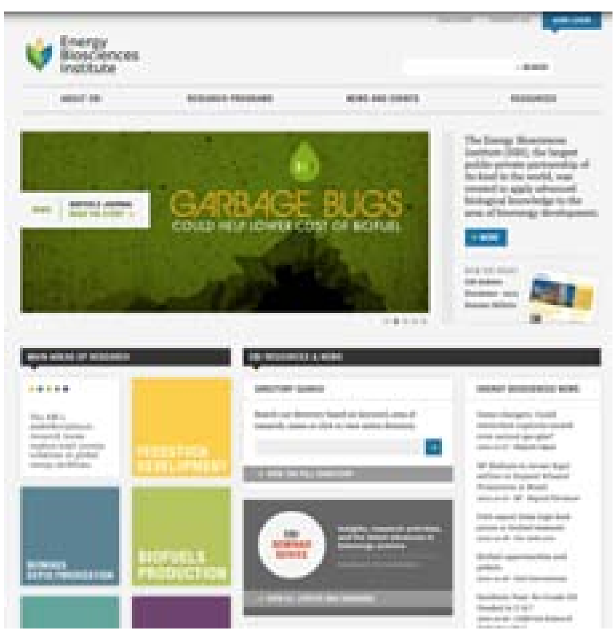
On the 5th anniversary of the EBI's founding, the upgraded site offers visitors a more user-friendly interface, additional features, more contact information for scientists, and a keyword-based search engine. All EBI personnel and programs are now accessible via improved and simplified navigation. Drop-down and accordion menus provide compactness and convenience in seeking information about the EBI.

The remake begins at the home page, where a rotating series of slides at the top highlight noteworthy EBI information and media coverage. Color-coded doorways lead to the main areas of research – complete listings of programs and projects, including relevant publications with each. One box previews upcoming events, another leads to job opportunities, and a third connects to the directory, enabling word or name searches.

A series of alternating news headlines, updated daily, keeps visitors informed of the latest from the field of bioenergy, while "EBI in the News" at the bottom of the page highlights the institute's announcements and appearances in the press. Finally, for EBI employees, a single-link portal to the EBI wiki is provided.

Across the top of the home page, navigational menus provide direction to everything from EBI background data to contact information and a comprehensive chronological list of all EBI research publications since 2008. Another section of the site archives all issues of the *EBI Bulletin*, the biannual magazine *Bioenergy Connection*, and the *EBI Annual Reports*.

There is a space for consumer tools developed by EBI researchers, proposal process instructions, and the entire EBI contract. The EBI Seminars page not only previews upcoming talks, but also provides links to video presentations of many prior seminars given since 2009.



EBI Managing Director Susan Jenkins supervised the year-long website evaluation and noted that, since the institute has grown significantly during its first five years, a new vision was needed.

"When the site was set up in 2007, it was intended to be basic and functional," Jenkins recalled. "Over time, as data grew exponentially and demands for our website similarly grew, we felt we needed a much simpler, more intuitive and more comprehensive tool to get visiting researchers, students and the general public more directly to their needs."

A core group of planners led by Ron Kolb, EBI's communications manager in Berkeley, and Nick Vasi, director of communications for the Institute for Genomic Biology at the University of Illinois, conducted website surveys, individual and focus group discussions, and website comparisons. They arrived at proposed design and technical solutions and vetted them with selected reviewers prior to launch.

Senior graphic designer Mirhee Lee and web developer Yoshi Kita, both on Vasi's staff at Illinois, developed the look, feel and navigation, and built the site using the open source content management platform, Drupal. In September, Diana Hembree was added to the Berkeley communications staff to maintain the website content and EBI's social networking tools.

"We are proud of what the team has done," Jenkins said, "but we are always looking for ways to improve. I encourage anyone who has thoughts about the website that would enhance its utility to contact us. As the EBI evolves, so will we."

DIESEL CONVERSION STORY SHOWCASES EBI'S CHARACTER

(cont. from page 1)

people only wanted to make acetone, or lately butanol, which results in a lot of 'byproduct.' This new route would convert the entire product slate into desirable diesel fuel molecules."

Enter UC Berkeley chemical engineers Doug Clark and Harvey Blanch, who lead the EBI effort in cellulose hydrolysis and product fermentation. They came up with the idea of using a solvent extraction technology to efficiently recover the ABE products from the fermentation broth. The result of the union was dramatic, as reflected in the journal *Nature* on Nov. 8. Toste, Clark and Blanch were co-authors of the article, "Integration of Chemical Catalysis with Extractive Fermentation to Produce Fuels."

EBI Director Chris Somerville called the discovery "iconic" for the institute. "It was a happy phenomenon," he said. "We learned of a problem, facilitated a collaboration, and provided the necessary analytical facilities. It's a perfect example of working together to make something novel."

Other co-authors of the study include former postdoctoral fellow Pazhamalai Anbarasan, graduate student Zachary C. Baer, postdocs Sanil Sreekumar and Elad Gross and BP chemist Joseph B. Binder.

The team explained how it produced diesel fuel from the products of a bacterial fermentation discovered nearly 100 years ago by the first president of Israel, chemist Chaim Weizmann. The retooled process produces a mix of products that contain more energy per gallon than the ethanol that is used today in transportation fuels and could be commercialized within 5-10 years.

"What I am really excited about is that this is a fundamentally different way of taking feedstocks – sugar or starch or eventually even lignocellulosics – and making all sorts of renewable things, from fuels to commodity chemicals like plastics," said Toste.

The late Weizmann's process employs the bacterium *Clostridium acetobutylicum* to ferment sugars into acetone, butanol and ethanol. Blanch and Clark developed a way of extracting the acetone and butanol from the fermentation mixture while leaving most of the ethanol behind, while Toste developed a catalyst that converted this ideally-proportioned brew into a mix of long-chain hydrocarbons that resembles the combination of hydrocarbons in diesel fuel.

While the fuel's cost is still higher than diesel or gasoline made from fossil fuels, the scientists said the process would drastically reduce greenhouse gas emissions from transportation, one of the major contributors to global climate change.

Tests showed that the new mix burned about as well as normal petroleum-based diesel fuel. "It looks very compatible with diesel, and can be blended like diesel to suit summer or winter driving conditions in different states," said Blanch.

The process is versatile enough to use a broad range of renewable starting materials, from corn sugar (glucose) and cane sugar (sucrose) to starch, and would work with non-food feedstocks such as grass, trees or field waste in cellulosic processes.

"You can tune the size of your hydrocarbons based on the reaction conditions to produce the lighter hydrocarbons typical of gasoline, or the longer-chain hydrocarbons in diesel, or the branched chain hydrocarbons in jet fuel," Toste said.

The fermentation process, dubbed ABE for the three chemicals produced, was discovered by Weizmann around the start of World War I in 1914, and allowed Britain to produce acetone, which was needed to manufacture cordite, used at that time as a military propellant to replace gunpowder. The increased availability and decreased cost of petroleum soon made the process economically uncompetitive, though it was used again as a starting material for synthetic rubber during World War II. The last U.S. factory using the process to produce acetone and butanol closed in 1965.

Nevertheless, Blanch said, the process by which the Clostridium bacteria convert sugar or starch to these three chemicals is very efficient. This led him and his laboratory to investigate ways of separating the fermentation products that would use less energy than the common method of distillation.

They discovered that several organic solvents, in particular glyceryl tributyrate (tributyrin), could extract the acetone and butanol from the fermentation broth while not extracting much ethanol. Tributyrin is not toxic to the bacterium and, like oil and water, doesn't mix with the broth.

Blanch and Clark found that Toste had discovered a catalytic process that preferred exactly that proportion of acetone, butanol and ethanol to produce a range of hydrocarbons, primarily ketones, which burn similarly to the alkanes found in diesel.

"To make this work, we had to have the biochemical engineers working hand in hand with the chemists, which means that to develop the process, we had learn each other's language," Clark said. "You don't find that in very many places."

Clark noted that diesel produced via this process could initially supply niche markets, such as the military, but that renewable fuel standards in states such as California will eventually make biologically produced diesel financially viable, especially for trucks, trains and other vehicles that need more power than battery alternatives can provide.

"Diesel could put Clostridium back in business, helping us to reduce global warming," Clark said. "That is one of the main drivers behind this research."

-- Robert Sanders

EBI PUBLICATIONS: AUGUST-OCTOBER 2012

FEEDSTOCK DEVELOPMENT

Producer Perceptions and Information Needs Regarding Their Adoption of Bioenergy Crops, Maria Villamil, Myles Alexander, Anne Heinze Silvis, Michael E. Gray, Renewable and Sustainable Energy Reviews, 16(6), pp. 3604-3612, doi: 10.1016/j.rser.2012.03.033, August 2012.

Facilitating Feedbacks Between Field Measurements and Ecosystem Models, David LeBauer, Dan Wang, K. Richter, C. Davidson, Michael Dietze, http://www.esajournals.org/doi/pdf/10.1890/12-0137.1, Ecological Monographs, October 2012.

BIOMASS DEPOLYMERIZATION

Identification and Characterization of a Multifunctional Dye Peroxidase from a Lignin-Reactive Bacterium, Margaret Brown, Tiago Barros, and Michelle C. Y. Chang, ACS Chemical Biology, doi: 10.1012/cb300383y, October 10, 2012.

Integration of Chemical Catalysis with Extractive Fermentation to Produce Fuels, Pazhamalai Anbarasan, Zachary C. Baer, Sanil Sreekumar, Elad Gross, Joseph B. Binder, Harvey W. Blanch, Douglas S. Clark, and F. Dean Toste, Nature, doi: 10.1038/nature11594, November 8, 2012.

BIOFUELS PRODUCTION

Engineering Robust Control of Two-Component System Phosphotransfer Using Modular Scaffolds, Weston R. Whitaker, Stephanie A. Davis, Adam P. Arkin, and John E. Dueber, Proceedings of the National Academy of Sciences, doi: 10.1073/pnas.1209230109, October 15, 2012 online.

ENVIRONMENTAL, SOCIAL & ECONOMIC IMPACTS

Producer Perceptions and Information Needs Regarding Their Adoption of Bioenergy Crops, Maria Villamil, Myles Alexander, Anne Heinze Silvis, Michael E. Gray, Renewable and Sustainable Energy Reviews, 16(6), pp. 3604-3612, doi: 10.1016/j.rser.2012.03.033, August 2012.

Intake Fractions of Primary Conserved Air Pollutants Emitted From On-Road Vehicles in the United States, Agnes B. Lobscheid, William W. Nazaroff, Michael Spears, Arpad Horvath, and Thomas E. McKone, Atmospheric Environment, http://dx.doi.org/10/1016/j.atmosenv.2012.09.027, September 2012 online.

Grand Missions of Agricultural Innovation, Brian D. Wright, Research Policy, http://dx.doi.org/10.1016/j/respol.2012.04.021, October 22, 2012 online.

The Legal Profession's Critical Role in Systems Level Bioenergy Decision-Making, Jody M. Endres and Daniel Szewczyk, Pace Environmental Law Review (to be published Winter 2013).

Find links to all above publications at the EBI web site, www.energybiosciencesinstitute.org

MARKING A MILESTONE WITH TRIBUTES AND A GARDEN PARTY

With ceremonial flourish and a Chancellorial turn of the shovel, the Energy Biosciences Building and its companion demonstration garden received a formal christening on Dec. 10 in Berkeley, five years after the EBI's own debut as the world's premier bioenergy research center.

State legislators and city officials joined nearly 100 UC Berkeley researchers and administrators to dedicate the new building, opened in July. EBI Director Chris Somerville took the opportunity to dedicate a small garden on the south side of the building as the Robert and Mary Catherine Birgeneau Energy Garden, which will showcase potential biofuel feedstocks – miscanthus, switchgrass, prairie cordgrass, agave and poplar are planned – in honor of Chancellor Birgeneau's firm support of EBI and science research and education in general.

This honor is for "planting so many seeds for research, teaching and public service efforts on the campus," said Graham Fleming, Cal's Vice Chancellor for Research. "We hope that this spot will be a place for experimentation and reflection and for understanding nature's role in addressing the world's energy and climate challenges."

↖ Namesakes Robert and Mary Catherine Birgeneau prepare to plant the first Miscanthus in their demonstration energy garden

Chancellor Birgeneau and his wife then planted the garden's first feedstock variety – a two-foot miscanthus.

U.S. Rep. John Garamendi and California Assemblymember Bob Wieckowski (D-Fremont) both issued commendations, the latter thanking the EBI for "moving us toward a 21st century clean energy future."

While Somerville reviewed EBI's accomplishments over the past five years, EBI Associate Director Paul Willems ascribed the accomplishments to EBI's "open-endedness and unprecedented scale": $350 million over 10 years for academic research alone.

"We feel the EBI represents a great experiment for all involved," Willems said. "We have developed a reputation as one of the best bioenergy institutions in the world."

Birgeneau described the EBI as "beginning a remarkable scientific journey with a unique private-public partnership model. I look forward to the next five years of innovation and discovery enabled and enhanced by the state-of-the-art features of the Energy Biosciences Building."

– Bob Sanders

EBIBULLETIN

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Berkeley UNIVERSITY OF CALIFORNIA

ILLINOIS UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

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