U.S. DEPARTMENT OF ENERGY

jbei

Joint BioEnergy Institute

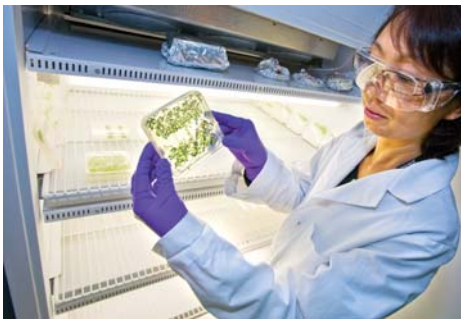
The Joint BioEnergy Institute (JBEI) is a San Francisco Bay Area scientific partnership led by Lawrence Berkeley National Laboratory (Berkeley Lab) and including the Sandia National Laboratories, the University of California (UC) campuses of Berkeley and Davis, the Carnegie Institution for Science and the Lawrence Livermore National Laboratory. One of three U.S. Department of Energy (DOE) Bioenergy Research Centers, JBEI is headquartered in EmeryStation East, a state-of-the-art laboratory building in Emeryville. JBEI's five-year mission is to advance the development of the next generation of biofuels — liquid fuels derived from the solar energy stored in plant biomass. Harnessing the solar energy in biomass could meet much of the nation's annual transportation energy needs without producing carbon emissions that contribute to global climate change. However, this requires technology-transforming scientific breakthroughs. To promote such breakthroughs and the rapid commercialization of its research, JBEI is organized into four interlocking divisions: Feedstocks, Deconstruction, Fuels Synthesis, and Technologies.

Feedstocks Division

The focus of JBEI research is on the efficient conversion into fuels of lignocellulose, the most abundant organic substance on the planet. A mixture of complex sugars and a tough material called lignin that provides strength and structure to plant cell walls, lignocellulose has the potential to provide biofuels that yield the same energy as gasoline and can be easily distributed through the existing pipeline and gas station infrastructure. However, lignocellulose is by nature highly resistant to "deconstruction" — being broken down into its constituent sugars.

Researchers in JBEI's Feedstock Division are developing specialty biofuel plants whose lignocellulosic biomass can be more easily deconstructed. This requires a better understanding of the genes and enzymes involved in the making of lignocelluose. JBEI researchers study rice as a genetic model for switchgrass and *Miscanthus*, two perennial grasses which have great potential as energy crops. They also study a type of mustard plant, called *Arabidopsis*, as a model for poplar, a tree that is highly touted as a future source of biofuels. These two model systems go from seed to mature plant in a matter of weeks, as compared to the year or more required for switchgrass, *Miscanthus* or poplar.

In addition, JBEI's Feedstock Division researchers are investigating the metabolic pathways involved in the production of lignin



with an aim toward increasing the tough material's susceptibility to deconstruction by enzymes or other chemicals. If successful, this research effort, unique to all the DOE Bioenergy Research Centers, will not only help with lignocellulose deconstruction, but should also help transform lignin into a valuable raw material.

Deconstruction Division

Researchers in JBEI's Deconstruction Division are developing new and improved ways to "pretreat" lignocellulose to enhance its deconstruction into fermentable sugars. Most current pretreatments for enhancing lignocellulose deconstruction utilize acids that result in an overall loss of sugars. These acids also yield by-products that inhibit the fermentation process, again resulting in an overall loss of sugars. The commercial production of advanced biofuels will require new enzymes that are capable of efficiently deconstructing both the sugar and lignin components of plant cell walls. To identify new enzymes, JBEI researchers are investigating heretofore unexplored microbial communities in a variety of environments, such as rain forest floors and composts. Since the rain forest floor is nutrient deficient, whereas composts are nutrient rich, the microbial communities that inhabit these two environments have evolved very different enzymes for lignocellulose deconstruction.

Once effective new enzymes have been identified, they will be studied at the molecular level to gain a better fundamental understanding of the different biological mechanisms used by nature to deconstruct lignocellulose. With this information, JBEI Deconstruction researchers will employ the latest genetic technologies, including synthetic biology and directed evolution, to design and engineer novel enzymes that are even more effective at breaking down lignocellulose biomass than those nature has provided. Unlike nature's enzymes, these synthetic enzymes will yield no unwanted by-products.

Technologies Division

JBEI researchers in the Technologies Division are finding ways to advance the scientific research that can speed the development of biofuels. For example, using high-throughput protein expression, purification and screening techniques, they are looking to generate thousands of gene clones per year, fully characterize the molecular machinery of plant cell wall synthesis, and perform functional analysis of tens of thousands of wild-type and synthetically engineered lignocellulose-degrading enzymes.

In the field of functional genomics, the genetic transcripts and protein profiles of natural and engineered organisms including plants will be fully characterized. This information will shed light on how specific types of molecular and cellular mechanisms are able to be successful. Metabolic pathways in modified organisms will also be profiled to optimize fuel production, and high-throughput glycomics (the study of the entire complement of sugars in a plant) will be performed. In the field of synthetic biology, JBEI researchers are developing new platform hosts for use in the production of enzymes and fuel molecules. They are also creating organic "parts and devices" that can be used in the engineering of new fuel-generating organisms and improved plants. In addition, they are developing new and improved technologies in the field of high-throughput imaging for the improved visualization of plant cell walls.

Fuels Synthesis Division

Sugars derived from starch-based biomass such as corn are simple and readily fermented, whereas the sugars derived from the deconstruction of lignocellulose are complex pentose (five-carbon) and hexose (six-carbon) sugars that contain chemicals which prevent them from being fermented by the most commonly used yeast, *Saccharomyces cerevisiae.* JBEI researchers in the Fuels Synthesis Division are using the tools of synthetic biology to engineer new microbes as an alternative to yeast that can quickly and efficiently ferment these complex sugars into advanced biofuels, as well as into other valuable chemical products.

Accomplishing this objective will require the development and improvement of fuel production systems in selected model microorganisms; the bacterium *Escherichia coli,* the yeast *Saccharomyces cerevisiae,* and the extremophile archaeon *Sulfolobus solfartaricus.* JBEI researchers are initially employing *E. coli* and *S. cerevisiae* strains that have been previously engineered to produce ethanol from five- and six-carbon sugars. All three hosts will be engineered to improve their tolerance to stresses that occur during biomass processing.

The tools of synthetic biology are also being used by JBEI researchers to engineer new biochemical pathways for the production of fuel molecules and chemicals that are currently derived from petroleum. Initially, pathways are being constructed and validated in *E. coli,* but when functional, will be introduced into *S. cerevisiae* and *S. solfartaricus.* JBEI researchers are specifically targeting next generation fuel molecules which could replace gasoline on a gallon-per-gallon basis in today's internal combustion engines.

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JBEI's Industry Partnership Program

As a DOE Bioenergy Research Center, JBEI is intended to serve as a crucible for fundamental scientific discovery and innovation. These discoveries and innovations can then be transferred to private industry for development into commercial products that will benefit the nation. To facilitate this transfer, JBEI actively seeks collaborations with private companies that have relevant scientific and market capabilities in energy, agribusiness and biotechnology. An Industry Partnership Program has been established that provides companies with specific opportunities to contribute to JBEI and become a part of the JBEI research community. There are four levels of partnerships in this program – Strategic, Topical, Venture Capital and Supporting – each with its own unique portfolio for investments, benefits and rewards. For more information about JBEI's Industry Partnership program and other collaborative opportunities, contact Pam Seidenman at JBEI's Business Development Office, (510) 486-6461, or PSSeidenman@lbl.gov

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DOE Bioenergy Research Centers

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