Energy & Biosciences Institute

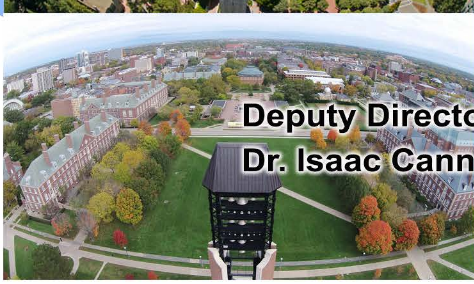
2018 Annual Report

Energy & Biosciences Institute

A partnership of three leading research institutions:
University of California Berkeley
University of Illinois Urbana-Champaign
Lawrence Berkeley National Laboratory

The Energy & Biosciences Institute provides access for industrial sponsors across the energy, chemical, mining, and agriculture sectors. Our partner network provides access to 7,500 faculty and PI's combined in addition to 100,000 student, postdoctoral, and professional researchers. Subcontracts can be established with other institutions.

EBI Director
Dr. John Coates



Deputy Director
Dr. Isaac Cann

EBI Administrative Staff from left to right: Shelley Brozenick, Drew Vaeth, Yi Liu, Sean Sotelo, Adele Wallrich

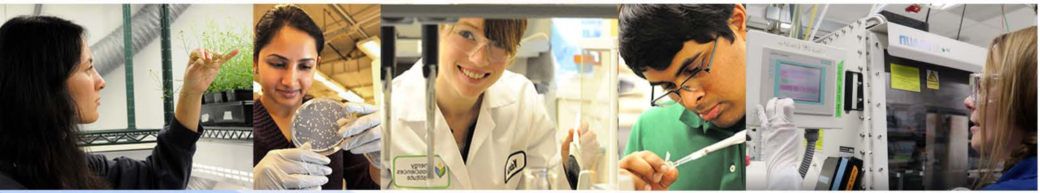




Energy & Biosciences Institute

EBI Overview

Charting the path to a sustainable energy future through collaborative science and technology development.



At the Energy & Biosciences Institute, we pursue cutting-edge research and development in carbon neutral energy alternatives and the advancement of principles that have the potential to reverse climate change. Our diverse portfolio of projects spans a wide array of approaches that cut across Chemistry, Biology, and Engineering. By bringing top scientists and engineers together in interdisciplinary mission-driven programs, the Energy & Biosciences Institute is poised to develop the next generation of batteries, energy storage systems, and sustainable fuels and chemicals. With this approach, we aim to upgrade the current energy matrix to more proficiently meet society's energy and power needs. The EBI does all this within a culture of true sustainability in regard to both our global environment and current market viability. We are organized around development of relevant and applicable alternative energy gauged by consistent product cycle and supply chain analysis that help us to better understand the obstacles facing implementation of game-changing technologies.

Our researchers come from a background of scientific distinction and have earned sustained excellence in their fields.

Our organizational structure provides conditions through which our sponsors are able to access outstanding researchers, scientists, and facilities; a closely coordinated and streamlined leadership; and dynamic partnerships that facilitate transformational breakthroughs, from bench scale to scale-up.

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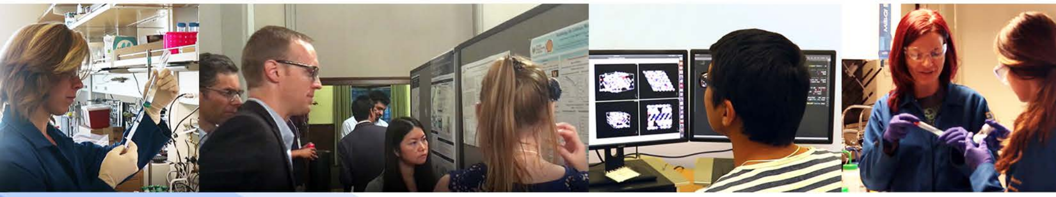
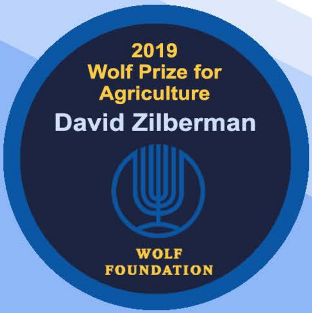
EBI Overview

A partnership of three of the world's leading research institutions and a community of award winning scientists.





We are very proud of recent efforts by EBI scientists whose insightful innovation, integrating chemistry and biology, has produced next generation sustainable biodiesel and useful lubricants. We are also incredibly pleased with the achievements and recognition for leadership in development of economic models to address fundamental issues within agricultural supply chain policy.

Support for the EBI mission can be contributed to the institute at large or tailored to specific research goals on a project-by-project basis giving sponsors the flexibility to explore and develop their research objectives. In alignment with our core research mission, the EBI also cultivates educational and entrepreneurial stewardship programs that identify and support aspiring scientists and science-driven start-up organizations. Together with our sponsors and partners, we can sustain a position of progress toward an ever-expanding energy sector and our global community at large for a brighter and renewable energy-paramount future.

The Molecular Foundry, Lawrence Berkeley National Laboratory, one of many unique advanced facilities found across our partnership campuses.

Want to learn more and get involved with our mission? Reach out and talk to us!
ebiadmin@berkeley.edu

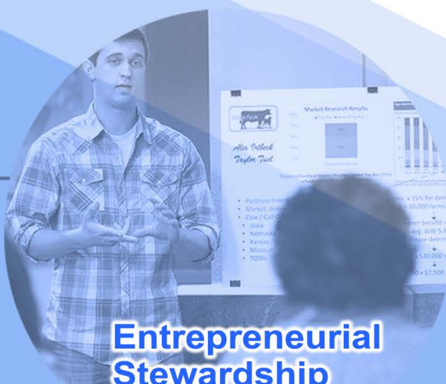
Energy & Biosciences Institute

Mission Pillars

Our operational model is designed to facilitate cutting-edge energy research while enabling the incubation of start-up enterprises and initiating progressive outreach within a diverse range of academics and K-12.

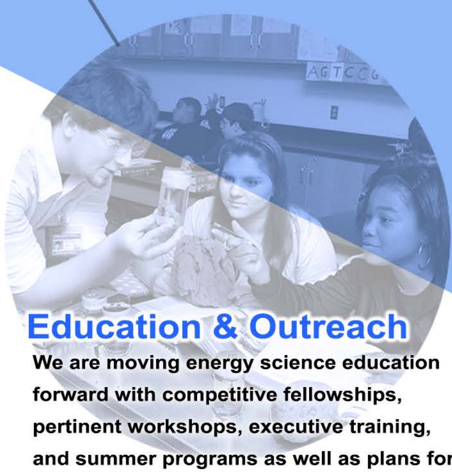
Core Research

The EBI is working to garner diverse sponsorship across the energy landscape to apply extensive interdisciplinary research and supplychain analysis into a wide range of energy solutions as well as novel waste treatment technologies that stand to improve the way society deals with production and reclaimation.



Entrepreneurial Stewardship

We are committed to providing dedicated lab facilities and equipment, industry insights, and connectivity in energy research and development for aspiring start-ups with our EBI^2 Small Business Incubator.



Education & Outreach

We are moving energy science education forward with competitive fellowships, pertinent workshops, executive training, and summer programs as well as plans for certificate programs in energy science entrepreneurialism and K-12 outreach.

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EBI Research Overview

The EBI specializes in a diverse portfolio of alternative energy research. By tailoring to a varied array of research in a collaborative institutional environment, we are able to bring together bright minds across interdisciplinary project work and cultivate greater advancements in energy science while training a progressive workforce in an environment of a more diverse energy landscape.

- **Computational Materials Science & Chemistry**
- **Technoeconomics and Supply Chain Analysis**
- **Novel Waste Identification & Treatment**
- **Biosciences & Bio-solutions**
- **Advanced Energy Storage**
- **Dense Energy Carriers**
- **Societal Impacts**

Applying a synergistic approach to the combined research disciplines of material sciences, engineering, chemistry, and biology, using supply chain analysis to inform and thoroughly address obstacles within every phase of our projects, we are able to bring valuable advancements to our sponsors. These results are aligned with public interests for our sponsors to deliver to the market for an encouraging energy future.

EBI partner facility, Institute of Genomic Biology, University of Illinois at Urbana Champaign

Energy & Biosciences Institute

Innovating Energy Solutions for Our Future

In 2018 the EBI faced new challenges in the efforts of alternative energy research. The decision was made to rebrand the institute, solidify promising research areas, and carry the mission forward.

2018 saw the strengthening of the relationship between the EBI and one of our sponsors, Shell International Exploration and Production Inc. We teamed up to hold the 2018 EBI Biannual Retreat with over 100 attendees. The agenda included research platform and poster presentations as well as presentations from Shell associates and representatives from the EBI Incubator Program.

We also held an EBI-Shell Workshop, piloted by David Zilberman of the UC Berkeley Department of Agricultural and Resource Economics and Elizabeth Endler of Shell, titled *Economic Considerations & Supply Chain Design for Implementing Innovations* arranging a collaborative forum for pushing innovation of supply-chain managment.

EBI partner facility, EBI/Coates Labs, Koshland Hall, UC Berkeley

Energy & Biosciences Institute

Researcher Spotlight

Our Principal Investigators and researchers work to innovate the energy landscape and bring viable solutions to the problems we face with our current power infrastructure.

Paul Kenis

"One of the problems society is facing is that we're emitting too much carbon dioxide (CO2) into the atmosphere now which leads to all kinds of unwanted effects. So we as a society need to go to ways by which we emit less CO2 but still can achieve the style of life that we're accustomed to. One way of doing that is to go to renewable energy sources that do not emit CO2 or emit less CO2. Another approach we are using here at the EBI is to take CO2 as a feedstock and use renewable energy to turn it back into useful chemicals and fuels. Imagine if we use CO2 and turn it back into fuels that we can use for transportation. Of course transportation will generate CO2 again but again that CO2 can be captured and now we have a carbon neutral cycle."

Elio Eliakim Tarika Endowed Chair in Chemical Engineering
Paul Kenis
I ILLINOIS

Sophia Ewens

"My project is inspired by the fact that right now we are in a global economic system in which energy production is slowly shifting from petroleum based fuels to non-petroleum based fuels. However, that transition is often constrained by the fact that we still need economic growth during that process. One option to replace petroleum fuels with alternative fuels is to use microbes to take CO2 from the atmosphere, which is essentially now deemed a pollutant, and transition it into a sustainable feedstock that we can use. Conceptually this would be replacing petroleum fuels with a brewed version where microbes can take CO2 from the atmosphere and make a liquid stock that we would typically be extracting from underground. I'm inspired by that vision and my research is focusing in on different energy resources we can use to fuel this process."

EBI-Shell Research Fellowship
Sophia Ewens
ebi Shell

Energy & Biosciences Institute

Energy Collection, Conversion, and Storage



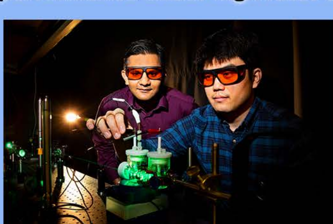
Energy comes in diverse forms that can be transformed from one to another. In fact this happens around us all the time. Every morning we convert electricity into mechanical, light, sound, and heat energy within our appliances. Electricity that was on its own converted from one form or another before reaching our outlets. The concept of energy storage can be beautifully captured by a simple analogy using our sun's energy. What happens if we want to use the sun's energy when the sun is not shining, i.e. at night or under varying cloud cover? With the proper planning and technology, we can access the sun's energy even under these circumstances by capturing and storing it to be available for use at a later time such as when demand is high and supply is low. As we transition to a period of energy diversification, storage strategies are moving to emphasize the capture and conversion of energy into a form that is not so easily stored at present. Work toward such scalable storage encounters many obstacles in making it safe, affordable, and convenient for use. For this reason, our current electricity storage is found variously in batteries, flywheels, compressed air, and pumped hydro storage systems. For short term storage, rechargeable batteries, such as the ones used in operating our cell phones, serve as the easiest examples. While such batteries have only a few years of life time, and hence are designated short term storage solutions, systems such as pumped hydro storage, which works by pumping water uphill into a reservoir during off peak hours for release to produce hydro-electricity on demand, can last for decades. The latter system is therefore considered a long-term solution. Other promising approaches where electricity is stored in a more versatile form, involve its conversion to chemical energy through electrolysis. Through this process, energy captured originally from wind and solar is initially converted to electricity and then is applied in electrolysis to generate methane and hydrogen which can be stored for longer periods or injected into the gas grid or even used as transportation fuels.

EBI partner facility, Advanced Light Source, Lawrence Berkeley National Laboratory

Projects by Area

Advanced Energy Storage (AES) - Increasing energy density and cycle life in a safe manner is central to successful and expanded deployment of electrochemical energy storage technologies across markets. Significant among the EBI interests in this area is to address fundamental questions about materials and devices used for electrochemical energy storage.

Our Advanced Energy Storage (AES) program is sponsoring research that has the potential to redefine the present understanding of electron storage and charge carrier transport processes within conductive media and electrode materials as well as at the boundaries between these phases. The AES program is also engaged in research that targets the discovery of material properties that operate cooperatively and in a self-stabilizing fashion. We are interested in battery chemistries that make use of metal anodes, multivalent systems, solid-state electrolytes, and other novel approaches to explore the key phenomena described above. Understanding the underlying principles fundamental to transport of ions, electrons, and quasiparticles within solid and liquid media involved in electrochemical energy storage is one of our paramount interests. Experiments designed to elucidate the mechanisms of particle transport in conductive glasses, semi-crystalline materials, ionic liquids and crystalline phases are also of interest to the EBI. Our AES portfolio also includes research aimed at monitoring the in situ dynamics of electron or ion shuttling at the interface and, given the tendency of electrical storage systems to degrade during cycling, we also aim to integrate the basic insights acquired from electrode architectures, electrolytes, and other cell components to enhance or achieve self-stabilizing performance under high rates of charge and discharge.



Chemistry professor Prashant Jain, left, and postdoctoral researcher Sungju Yu have developed an artificial photosynthesis process that converts excess CO2 into valuable fuels, bringing green technology one step closer to large-scale solar energy storage.

Secretary of Energy Early Career Research Program

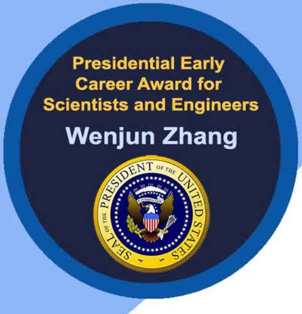
David Flaherty

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

Projects by Area

Dense Energy Carriers (DEC) – Solar energy is expected to become a significant component of our future energy mix worldwide. This expectation has been spurred by technological advances in photovoltaics and the consequent reductions in the cost of solar energy.

It is anticipated that within this century solar generation will become the cheapest form of energy. These electrons can however be stored more stably through their use in production of energy dense molecules such as hydrogen, alcohols, hydrocarbons or ammonia from sources such as water, carbon dioxide, and nitrogen. A good example here is the electrolysis of water into hydrogen and oxygen using solar energy and then converting the hydrogen and the greenhouse gas carbon dioxide to methanol by means of chemical or biological processes. At the EBI we foster research aimed at solar driven synthesis of Dense Energy Carriers (DEC). Studies under DEC include projects that aim at discovery and fundamental understanding of natural and designer materials as well as the challenges facing their application into photovoltaics; device architectures that allow for collection of hydrogen over large areas in water-splitting devices; breakthrough concepts of hydrogen production that demonstrate either higher efficiency or better costs than current technologies; novel high efficiency solar harvesting systems; and an integrated system of carbon dioxide reduction that leads to synthesis of carbon-based molecules imbued with high energy densities.

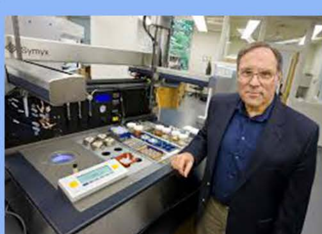


EBI partner facility,
Joint Center for
Artificial Photosynthesis,
Lawrence Berkeley
National Lab

Projects by Area

Methane to Products (M2P) - Conversion processes of great importance in achieving a crude-oil independent supply of energy, fuels, and chemicals for the future.

As the world's economies move towards sustainable carbon neutral energies, the market for chemicals is expected to keep growing. Methane, although currently derived from fossil fuel sources, can be seen as an ideal transition molecule because it can also be readily produced through sustainable means including plant biomass degradation, organic waste treatment, and atmospheric carbon dioxide reduction. Within the EBI partnerships we aim to covert methane to high-value large volume products, such as drop in liquid fuels or commodity chemicals. We seek to harness the recent breakthroughs in electrochemistry, nanomaterials, catalysts, computational sciences, and synthetic biology all utilized with cost effective electron sources such as photovoltaics to develop new approaches for methane conversion to valuable products.

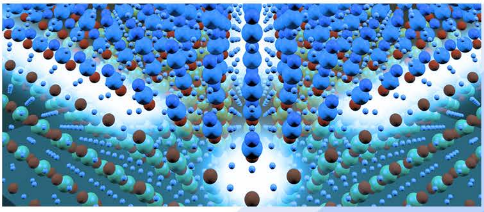


EBI researcher, Alexis Bell, conducts fundamental studies of the electrochemical oxidation of water and the reduction of CO2, experimental and theoretical investigations of catalyst structure-function relationships, and simulation of electrochemical cells used for the reduction of CO2 to fuels.

Two of our researchers have recently received the PECASE award; the highest honor bestowed by the United States Government to outstanding scientists and engineers who are beginning their independent research careers and who show exceptional promise for leadership in science and technology.

Projects by Area

Computational Materials Science & Chemistry (CMS) - Theoretical prediction of the electronic and structural properties of materials to chemical kinetics and equilibria.



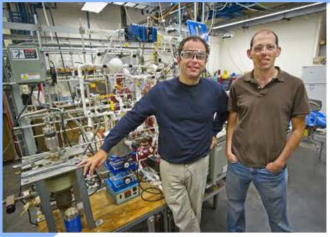
Experience has taught us that scientific advances that rely solely on empirical research for advancement can be very expensive and time consuming. Application of this approach in our efforts to advance renewable and carbon neutral technologies will suffer the same consequences. A chemist or a chemical engineer knows that the selection of the right materials and formulating the right combinations, as well as the right architecture for optimal performance for a given application or reaction, can be daunting. To engender rapid discovery in the materials and chemistry areas, the EBI and its partners aim to use computational tools and the development of new computational approaches and techniques to build a renewable energy research technology portfolio. The tools developed under the computational material science and chemistry program are expected to be applicable to all themes across the EBI and therefore help to develop new capabilities required to address fundamental questions in the area of energy transition. The targeted areas include high throughput virtual screening, modeling solid-liquid interfaces, modeling fundamental processes to device optimization for solar to fuel conversion, modeling of materials for separation, and multiscale approach for novel catalysts.

EBI partner facility,
Joint BioEnergy Institute,
Emeryville, CA (DOE)

Projects by Area

Biosciences & Bio-solutions (BIO) - At the EBI, where we cut our teeth by harnessing biology to create fuels of tomorrow, we recognize that chemistry and engineering alone will not lead to the world's desired energy solutions. Biological processes have a role to play and have potential to yield game-changing technologies that produce sustainable energy on a large scale.

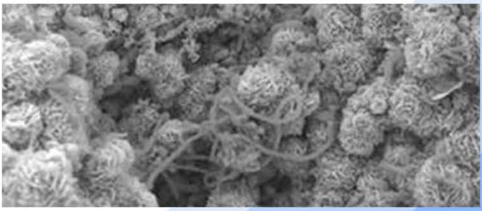
Plants fix large amounts of energy from our sun in the form of biomass, and the common yeast has been used over millennia to produce ethanol from plant matter. The current production of ethanol as a biofuel from corn and sugarcane is a mature technology; however, we also know that microorganisms, such as members of the Clostridial family, are able to produce hydrogen directly from sugars derived from plant-fixed biomass. Furthermore, microbes from the methanogenic archaea are known to use a variety of gaseous and liquid substrates, such as hydrogen and carbon dioxide, methanol, and acetic acid to produce methane. The EBI partners, with our one of a kind bioenergy research farm at University of Illinois, access to state of the art fermentation plants both at Illinois' Integrated Bioprocessing Research Laboratory (IBRL) and at Berkeley's Advanced Biofuels Process Demonstration Unit (ABPDU) and exceptional biological engineering and microbiology faculty are harnessing and manipulating microbial pathways to produce fuels or their intermediate products. The latter products are also amenable for conversion to energy dense fuels or chemicals in an environmentally friendly and sustainable way through coupling with other microbial pathways or chemical catalysis.



EBI researcher, Dean Toste (left), conducts research in development of catalysts, catalytic reactions and methods for organic synthesis to address problems in the synthesis of complex molecules possessing interesting structural, biological and physical properties.

Projects by Area

Soured Systems Biology (SSB) - Metal corrosion from chemical and biological activity impacts virtually all industries. The global cost of corrosion due to prevention, inspection, maintenance, repair, and lost revenues is estimated to approximately $1 trillion annually.



This is of particular concern to the oil and gas industry which is largely comprised of susceptible carbon steel infrastructure carrying ecologically disasterous fluids. Inadvertent and uncontrolled microbial production of the toxic, corrosive, and explosive gas, hydrogen sulfide (termed “souring”) during crude oil production operations is the root cause of numerous facility failures, toxic releases, and environmental contamination. At the EBI we are working to develop a fundamental understanding of reservoir souring through research with the microbes associated with it. By studying several components of microbial sulfate reduction using the latest techniques, we can develop a conceptual understanding of the process that may enable control of these environments and prevention, reversal, or minimization of souring through more in-depth understanding of mechanisms of control by nitrate addition and the constraints of its application. In this line of research we will continue to develop geochemical models of souring and its control in fractured systems, develop new technologies for early warning of souring onset, and characterize new inhibitors in comparison to nitrate and traditional biocides such as Tetrakis Hydroxymethyl Phosphonium Sulfate (THPS). The aim of our ongoing research program is to develop a deeper understanding of the biogeochemical processes underlying microbial sulfate reduction in oil reservoir environments.

Projects by Area

Technologies for Improving Feedstock Production and Harvest (TIF) - The EBI has a strong interest in working with its partners, especially from industry, to continue its efforts aimed at developing concepts that will lead to a highly mechanized approach to feedstocks cultivation for next generation biofuels in a safe, efficient, and scientifically sound manner.

With this in mind, the EBI and its earliest sponsors established the largest bioenergy research farm at University of Illinois at Urbana-Champaign. This facility boasts of a field Research Center equipped with equipment for all aspects of feedstock production, from planting through harvesting, and a fully equipped facility for equipment fabrication and maintenance, biomass processing and storage, and a large greenhouse. The instrumented 320-acre field also allows large scale trials on continuous measurements of greenhouse gases, soil carbon, run off, and other factors likely to impact the environment due to the establishment of the large-scale farms needed to supply feedstock to an operational bioenergy plant. Our participating institutions have the expertise to ask questions in the areas of feedstock establishment and removal, pests and pathogens, productivity of diverse feedstock, genomics of feedstock, predictive models, effect of biodiversity, life cycle analysis, effect of soil carbon and run-off, comparison of alternate land-use, and invasiveness of non-native vegetation. We have also developed a gantry sensing system that allows the collection of proximity data on energy crops. For efficient harvesting of bioenergy crops, we have also been developing feedstock harvesting systems that incorporate instrumentations that monitor driver behavior, anti-collision technology, and automated braking systems into farm implements, all aimed at modernizing biomass production systems in anticipation of their eminent deployment.

EBI^2

Entreprenurial Business Incubator

The EBI is dedicated to the innovation of market applicable research science. In its efforts to produce renewable solutions to the energy sector, the EBI has developed a small business incubator program thereby creating incentive for researchers to spark their own creative business applications aligned with energy and bioscience. The space, located at Koshland Hall, UC Berkeley, consists of 3000 square feet of dedicated facilities including analytical instruments, benches, desk space, as well as a shared suite of designated equipment. We offer start-ups the ability to move in right away and flexibility of space agreement for entrepreneurs requiring only equipment access.

SUGARLOGIX

VISOLIS

Pow Genetic Solutions

BERKELEY BREWING SCIENCE

synvitrobio

OGMA

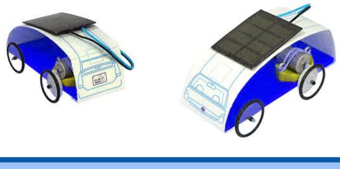
Our Incubator Lab is managed by Yi Liu, MS in environmental science. Yi oversees the daily operations of the incubator program and provides training and oversight to the lab space. Yi is an accomplished environmental scientist with years of experience in general lab and equipment management as well as lab safety.

Contact Yi: yiliu89@berkeley.edu

Educational Outreach

We are working constantly to develop and evolve our educational program to prepare generations of diverse energy science leaders by engaging with undergraduates in field oriented learning, mentorship, and professional training. We're also cultivating partnerships in coordination with extra-campus initiatives to create a viable outreach platform for K-12 and the community at large for advancing the understanding of energy sciences and its importance in the world today.

Our Education Program is managed by Adele Wallrich, a recent UCB graduate in Conservation and Resource Studies. Adele will be spearheading development of the EBI's educational and outreach core mission directive, managing both undergraduate support and primary education outreach programs.



Contact Adele: awallrich@berkeley.edu

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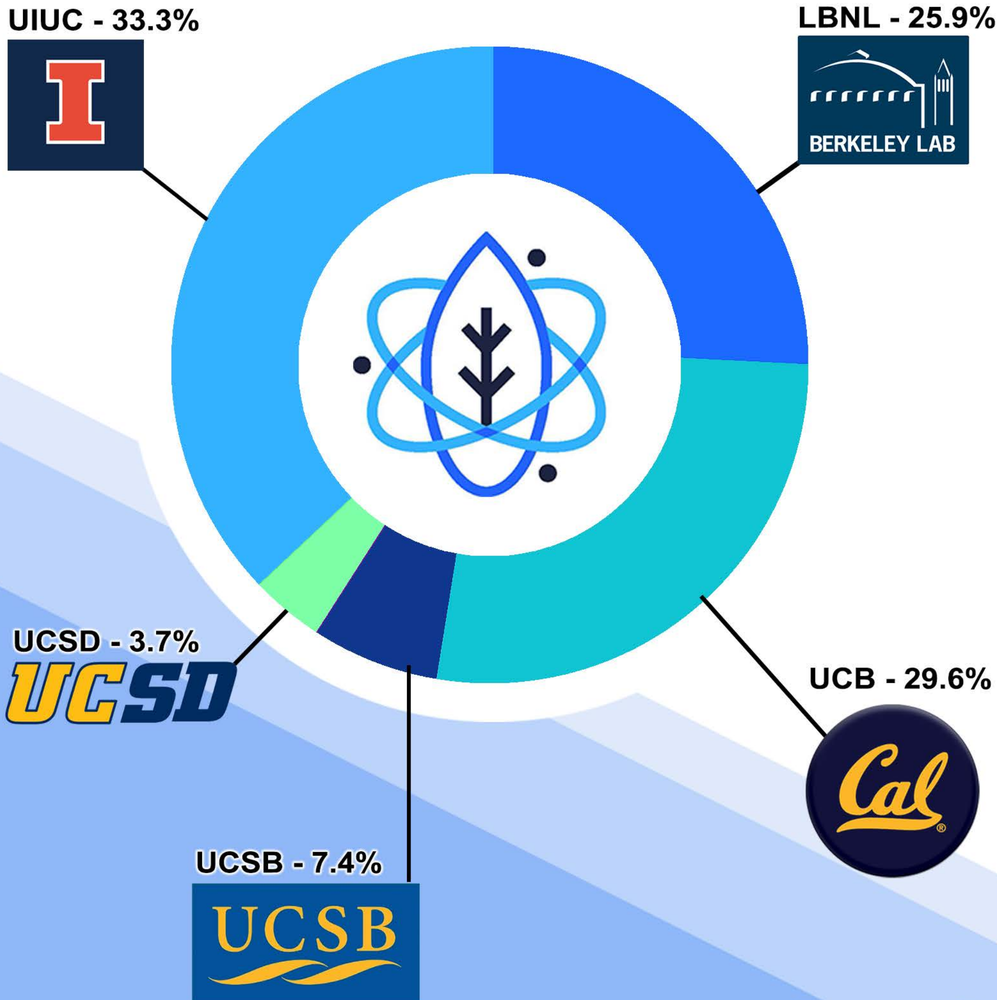
Project Distribution

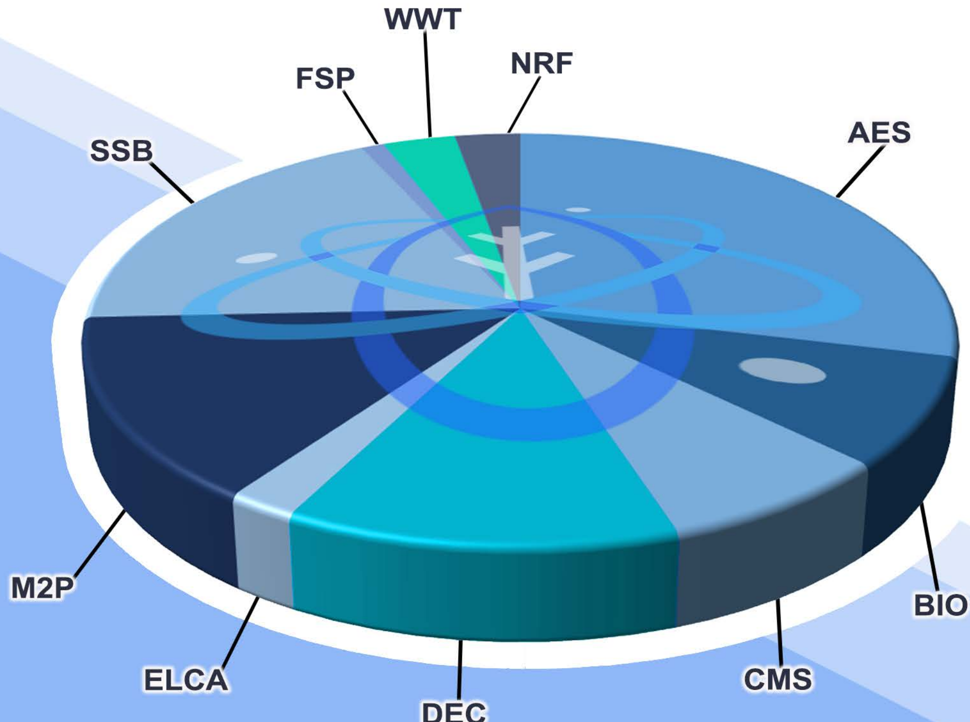
The EBI works across multiple campuses in concert with its partnerships and sponsorships to bring a vast array of research to the table.



Energy &
Biosciences
Institute

Leveraged Funding

The EBI has garnered support for our diverse projects in energy research with our most recent leveraged sponsorship hitting about $16 million at the year two milestone.



Advanced Enregy Storage (AES)	29%
Biosiences & Bio-solutions (BIO)	8%
Computational Materials Science (CMS)	8%
Dense Energy Carriers (DEC)	13%
Economic Life Cycles (ELCA)	2%
Methane to Products (M2P)	14%
Soured Syetems Biology (SSB)	19%
Feedstock Production (FSP)	1%
Wastewater Treatment (WWT)	3%
Novel Routes to Fuels and Chemicals (NRF)	3%

Energy & Biosciences Institute

Research Mission Timeline

Advancing Energy through Science

Diverse Sources **Unifying Storage** **Utilization**

The EBI maintains a mission of sequestering carbon through the development of useful processes that advance the energy landscape while continuing to meet the power demands of society. Right now that means optimizing fossil fuel systems while continuing to improve alternatives. In the near future that applies to progressing utilization of sustainable chemical and biological intermediates to reduce the carbon footprint of fuels and hybridizing energy use. In the longer term our work is moving to bring clean energy sources to market.

Research toward a Clean Energy Future