

CO₂ at LBNL

Blake Simmons Division Director Biological Systems and Engineering 9/13/22

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ERG

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Berkeley Lab Overview

- One of the world's leading research institutions:
 - The first of 17 national laboratories
 - \$1.1 B budget; 4,000+ staff
 - Six research areas
- Five major research facilities serving 14,000 users
 > 1/3 of all national lab users

VERSITY

CALIFORNIA

- Solutions addressing critical energy and environmental challenge
- Managed by the University of California... with 2,000 annual journal publications, the most productive relationship between a national laboratory and university system
- 14 Nobel Prizes
 15 National Medals of Science
 86 members of the National Academies (4% of membership)







The "Solutions Department*"



Ernest O. Lawrence founded Berkeley Lab in 1931 to pioneer "Big Science:"

- Ambitious goals
- Long term, mission-driven research

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Interdisciplinary teams

ENERGY

- Large user facilities

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Lab "Big Science" continues to deliver solutions to big challenges

*Secretary Jennifer Granholm U.S. Department of Energy

Berkeley Lab Biosciences Area – FY 2022



- DOE's largest bioscience research operation
- 949 staff and 351 affiliates
- ~\$190M in funding
- 3 Scientific Divisions and a User Facility

- Biological Systems and Engineering
- Environmental Genomics and Systems Biology
- Molecular Biophysics and Integrated Bioimaging
- Joint Genome Institute

Scientific	269	+10
Technical	149	+1
Operations	79	
Faculty	68	+2
Postdoc	192	+3
Graduate	137	+1
Undergraduate	55	
Affiliates	351	



Biosciences' Long History at Berkeley Lab



Birthplace of Nuclear Medicine with John Lawrence



- Led to the development of modern PET imaging
- Strong Alzheimer's program to this day (NIH supported)
- Ongoing programs on impacts of radiation, funded by iARPA

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Unlocking the Secrets of Photosynthesis



- Melvin Calvin established the Chemical Biodynamics Division at LBL the 1960s
- Has led to energy solution programs like JCAP & LiSA
- Basic research into
 photosynthesis continues

The Human Genome Project



- Berkeley Lab played a key role in the DOE human genome project
- Led to the creation of the Joint Genome Institute, DOE's sequence facility
- Genomic information
 underpins modern biology

Supporting the Bioeconomy and Biomanufacturing

The Bioeconomy

- Economic activity that is driven by research and innovation in the life sciences and biotechnology, and that is enabled by technological advances in engineering and in computing and information sciences.
- Estimated to be about \$1T in 2020





LIFORNIA

BIOTECHNOLOGY



DATA





Strategic application of biotechnology through biomanufacturing is enabling innovation and impact in many sectors







Creating a Net Negative Carbon Enterprise



Creating a **Circular Carbon** Economy





Products



Earth-based Negative Emission and Carbon Management Solutions





LBNL's CARBON MITIGATION RESEARCH

Developing Science and Technology for Negative Emissions at Scale

Earthbased Negative Emission and Carbon Management

Extended weathering via soil amendments for negative C emissions



Terrestrial carbon sequestration





Turning Carbon into Products

Synthetic biology to transform biomass into biofuels and bioproducts



New ways to produce solar fuels using sunlight, water and CO2 inputs

JCAP JOINT CENTER FOR ARTIFICIAL PHOTOSYNTHESIS

Biofuels and Biomanufacturing



SCIENCES





Direct Air Capture

Capturing concentrated flue gas



Direct Air Capture for diffuse atmospheric CO₂ using MOFs





ENERGY TECHNOLOGIES AREA (ETA)

Turning Carbon into Products





Biofuels: Synthetic biology to transform biomass into biofuels and bioproducts



Solar Fuels: Discovering new ways to produce fuels using sunlight, water and CO2 inputs



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Electrofuels/products: Using a single reactor to convert CO2 and electricity into bioproducts

Electrochemical Refinery: $H_2 + CO_2 +$ electrons

Biomanufacturing







Direct Air Capture





- Recent Efforts: MOFs to capture concentrated flue gas
- Current Efforts: DAC for diffuse atmospheric CO₂, which requires significant cost reduction and new materials for efficient capture, separation of gas and regeneration of absorbant

CNI FY22 LDRD Suite

Chosen to initiate early stage research on new & important directions



Natural System Capture, Store, Track

Extended weathering via soil amendments for negative C emissions (Hang Deng, EESA w/ETA, BSA)





NonDestructive Measurement of Carbon Distribution Soil for carbon sequestration (Arun Persaud, PSA w/





Cyanobacterial Systems for Accelerated Capture in Seawater (Peter Agbo, BSA)





BIOSCIENCES P.D. ADAMS Associate Laboratory Director

COMPUTING SCIENCES

J.T. CARTER Associate Laboratory Director

EARTH & ENVIRONMENTAL SCIENCES

S.S. HUBBARD Associate Laboratory Director

ENERGY SCIENCES

J.B. NEATON Associate Laboratory Director

ENERGY TECHNOLOGIES

R. PRASHER Associate Laboratory Director

PHYSICAL SCIENCES

N.A. ROE Associate Laboratory Director

Technoeconomic analysis (Breuning, ETA)

Accelerated Electrochemical Direct Air Capture and Direct CO2 Dissociation

Towards Accelerated Electrochemical Direct Air Capture in Noaqueous Solvents (Andrew Haddad w/ESA)



Electrochemical regeneration of aqueous alkaline sorbent Bryan McCloskey, ETA w/ESA)





Direct CQDissociation Technologies for O Production (Vassilia Zorba, ETA w/ESA)





New S&T Directions: C1 Biomanufacturing

- **Goal:** develop carbon negative technologies that incorporate CO₂ into biomanufacturing
- **Approach**: Leverage LBNL capabilities in synthetic biology, bioprocessing and technology development to establish hosts that can convert CO₂ to biofuels and biochemicals







PI: S. Singer

New S&T Directions: Methylomicrobium Bioengineering for Negative Carbon Emission Bioproduct Synthesis

Biology can bring one-stop solution to carbon capture, storage and utilization.

<u>Motivation</u>: To propel carbon-negative technologies we need diverse microbial hosts, advanced genetic tools, native/engineered and efficient carbon conversion routes.

<u>Goal:</u> Engineer non-model microbe (methanotrophs) for bioconversion of methane (GHG) to commodity biochemical, processed into long shelf-life products.

Point Source Capture



Landfill



Oil & Natural gas

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Bioengineering Tools



Methanotroph

- Using CH₄ (highly potent greenhouse gas) as a feedstock
- Employing **CO**₂ for increasing product yield
- Bioconversion at **30°C** and ambient pressure.
- Unique pathway designing to produce a non-native product, malonic acid-DOE top list of chemical





PI: D. Awasthi

New S&T Directions: Carbon-efficient biomanufacturing from gas molecules in microbial electrochemical fluidized bed reactors (LDRD)

Aims to solve a key technological bottleneck in C1 biomanufacturing from gas molecules by desiging a a fluidized electrode bioreactor for CO₂ conversion

.CO2

Organics

Electricity as energy source for microorganism to fix CO₂



High catalytical area: maximized catalyst area/volumen reactor ratio

Optimized electrode-gas-bacteria interaction: better conversión rates



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CO2formate Organics Gas (CO₂) Fluidized electrode

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of substrate



PI: S. Tejedor Sanz



New S&T Directions: Decarbonizing industry through acetogenic consortia (LDRD)

High-value products based on inexpensive, abundant and widely accessible C1 inputs



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Biomanufacturing: Agile BioFoundry (ABF - EERE)

- Goal: Enable a decarbonized U.S. economy by reducing the time and cost to market of bioprocesses by 50% for the production of sustainable chemicals, performance advantaged bioproducts, and sustainable aviation fuels
- Major Accomplishments: 3 demonstrations of bioprocess development 50% time / cost savings; 15 ABF microbial hosts successfully scaled to 10 L and above; deployed new software tools for predictive biology
- Industry/Academic Collaborations: Since 2017 there have been 25 projects with industry and academia that leverage the capabilities of the ABF in biomanufacturing
- New Initiatives/Programs: Directed Funding Opportunities with NSF, MSRDC, and BioMADE

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Scaling Biology: Advanced Biofuels and Bioproducts **Process Development Unit (EERE)**

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