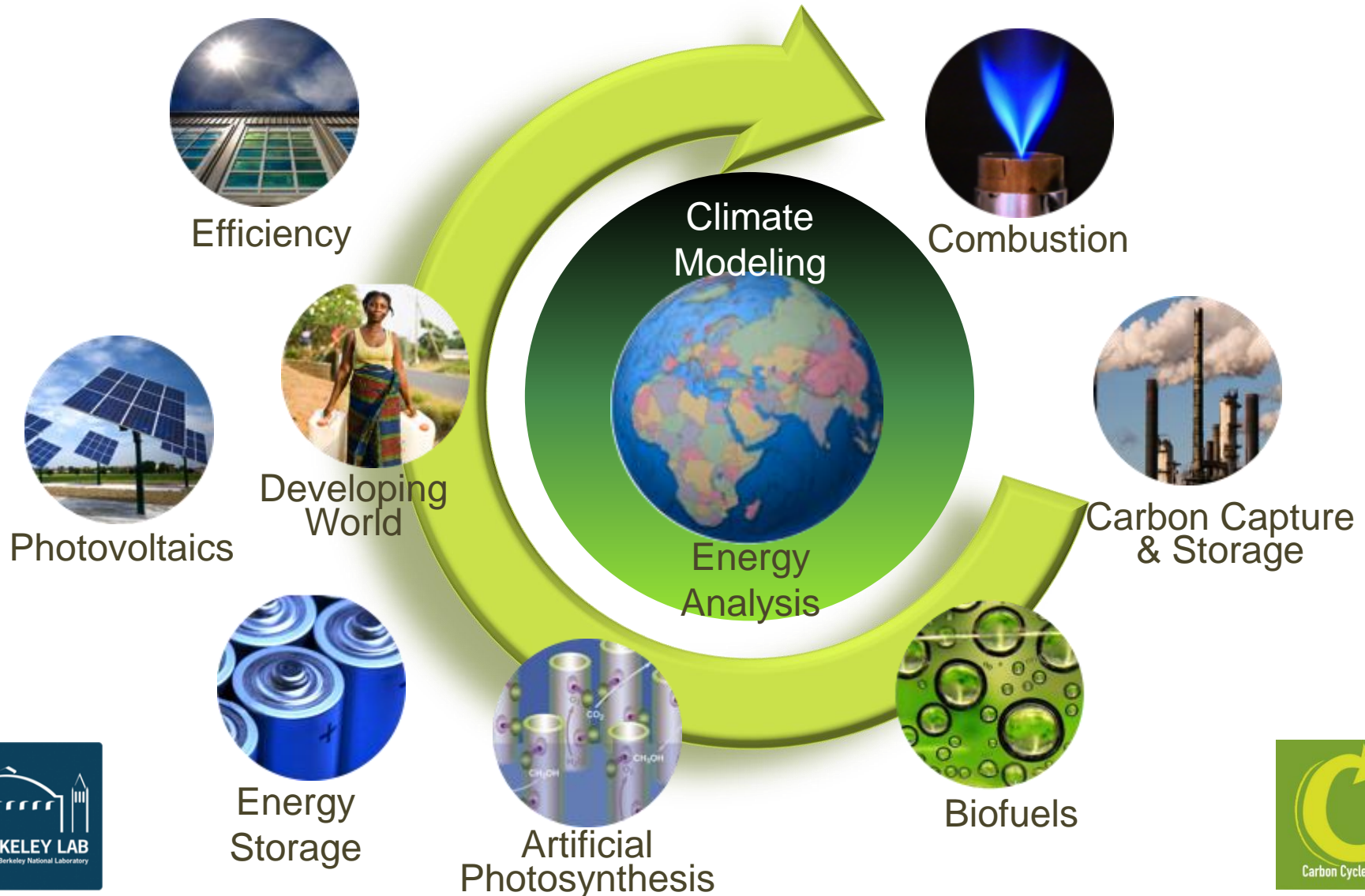


# Carbon Cycle 2.0

Pioneering science for sustainable energy solutions



# Carbon Cycle 2.0 is...

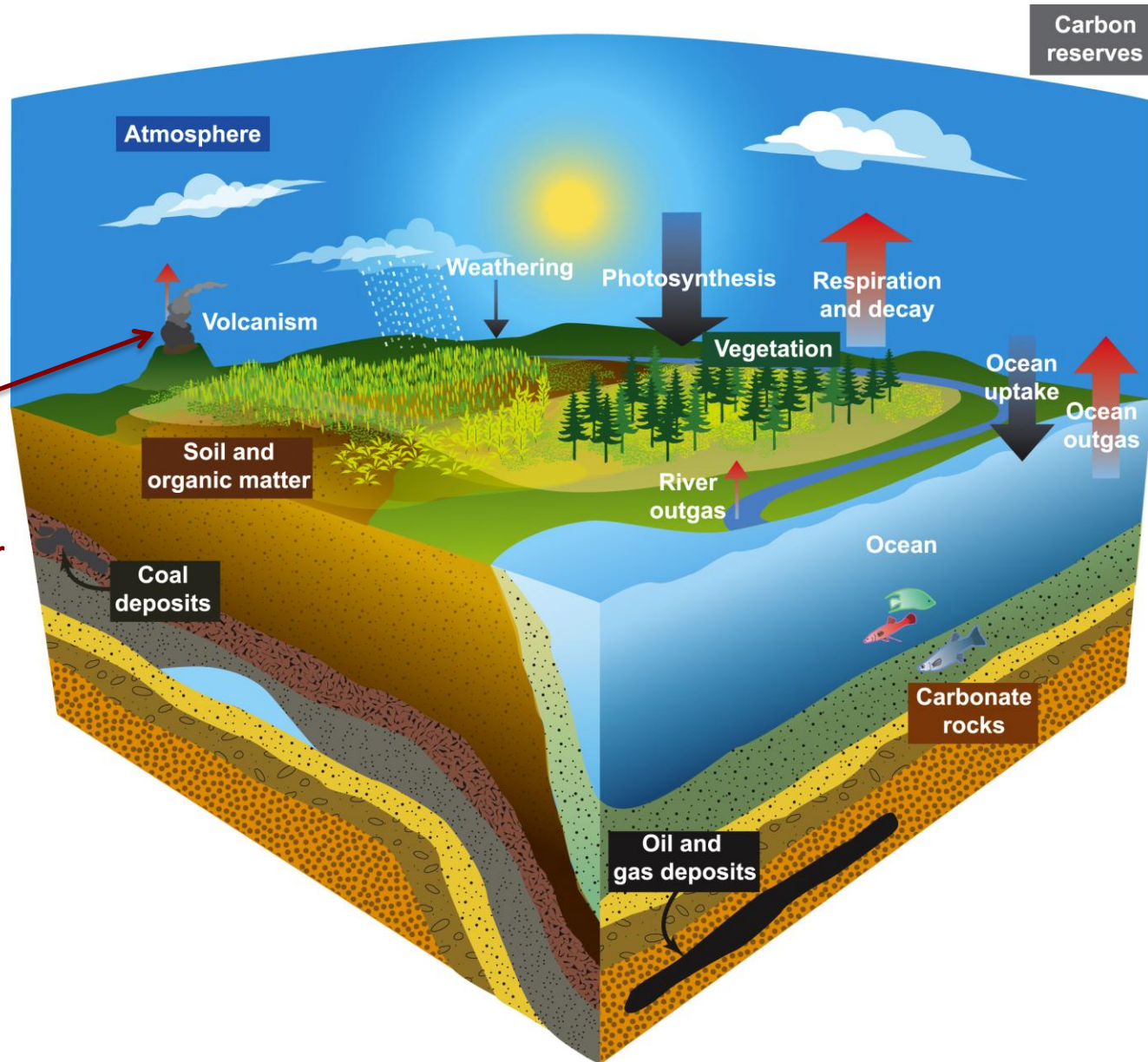
1. A vision for
  - a global energy system integrated with the Earth's natural carbon cycles
  - an interactive Berkeley Lab environment with a shared sense of purpose
2. A program development plan that will allow us to deepen our capabilities and provide more opportunities to have impact
3. An attempt to integrate our basic research with applications using models of technology deployment constraints
4. Set of internal activities aimed at priming the effort
  - LDRD investments to stimulate interactions
  - Seminar series (pl.) to disseminate information
  - Web tools to promote collaborations
5. Outreach and networking
  - Community education
  - Industry advisory structure



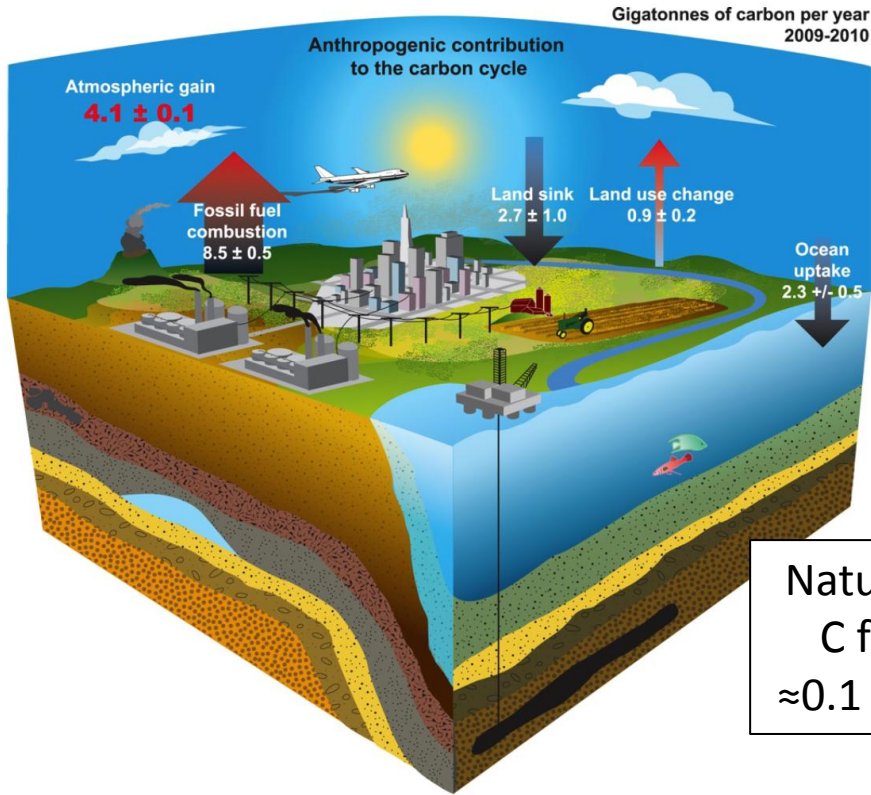
# Carbon Cycle 1.0: Natural Carbon Cycle

Rapid exchange of carbon between atmosphere, biosphere & surface ocean

Very small NET carbon fluxes – 0.1 to 0.2 Gt C/yr



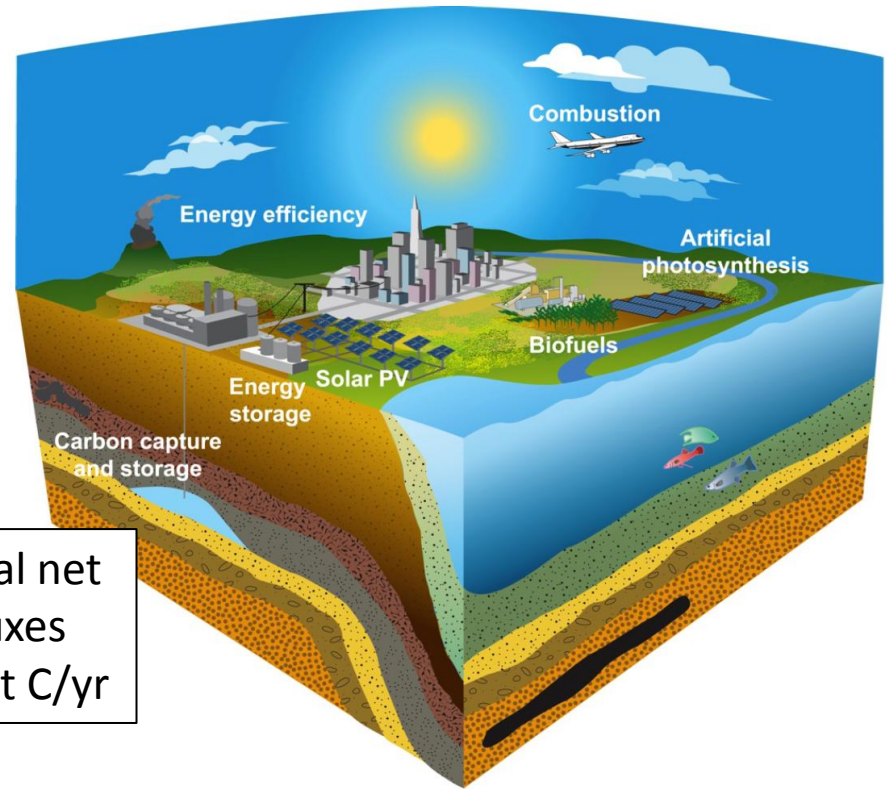
# Current open-ended C cycle Carbon Cycle 1.x (2010 AD)



140 PWh/yr energy production  
8.5 Gt/yr carbon emissions

60 Mt C / PWh

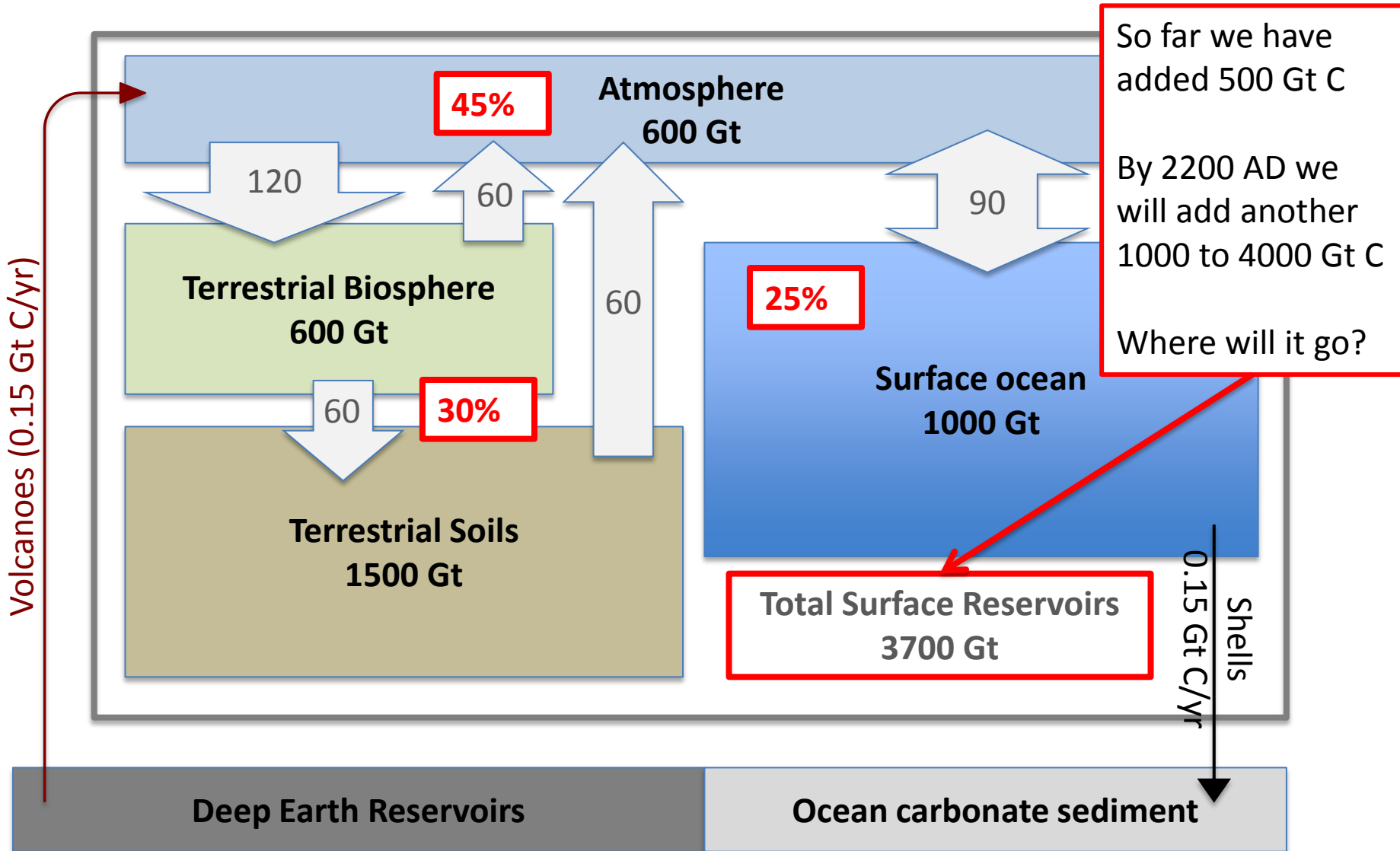
# Future balanced C cycle Carbon Cycle 2.0 (2100ff AD)



400+ PWh/yr energy production  
 $\leq 3$  Gt/yr carbon emissions

$\leq 7.5$  Mt C / PWh

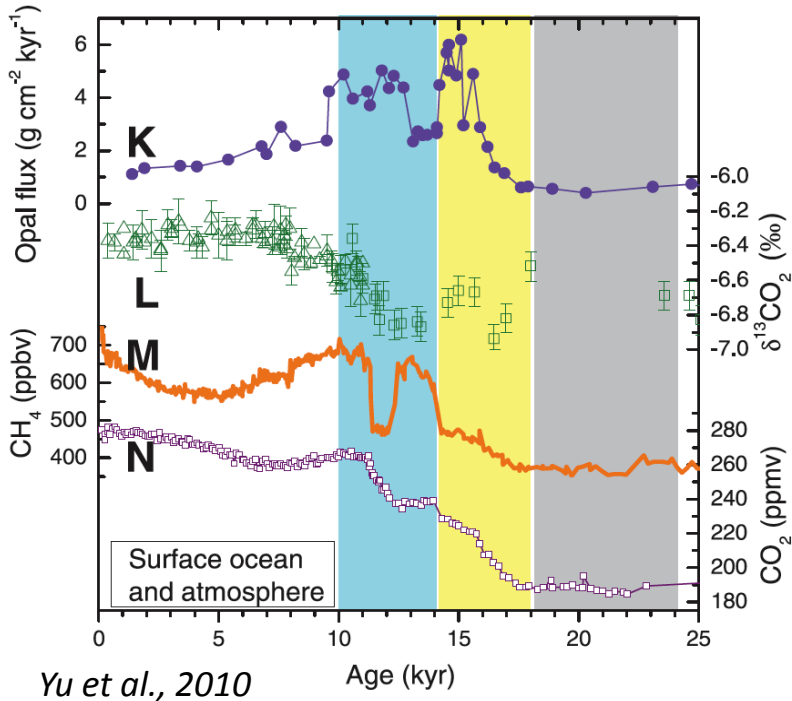
# Box model version of global carbon cycle



\*Fluxes in Gt C/yr

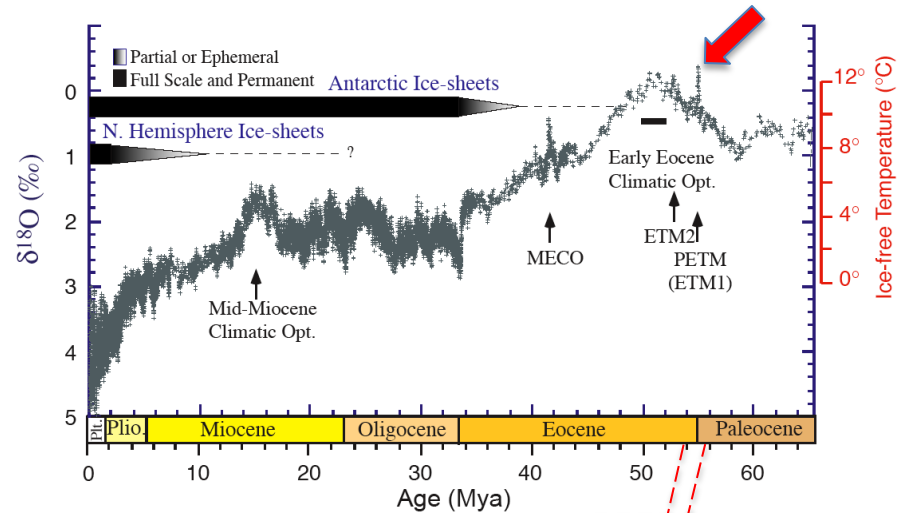
# Carbon has never before been moved around as fast as today's 10 Gt/yr....

Last Glacial-to-interglacial transition: <0.1 Gt/yr



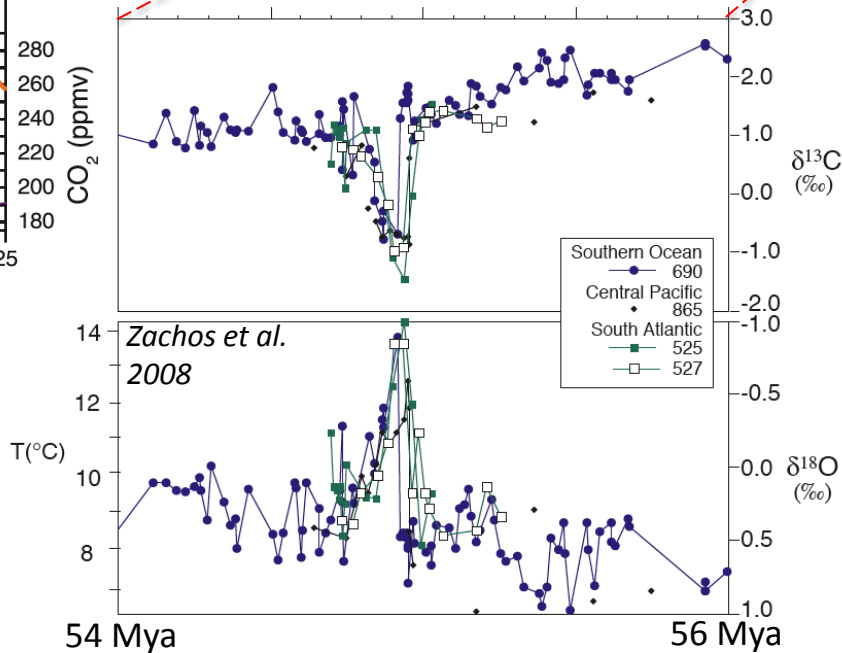
Yu et al., 2010

150 Gt C in  
6000 yr  
(0.025 Gt/yr)



Paleocene-Eocene thermal maximum

3000 Gt C in  
6000 yr:  
(0.5 Gt/yr)



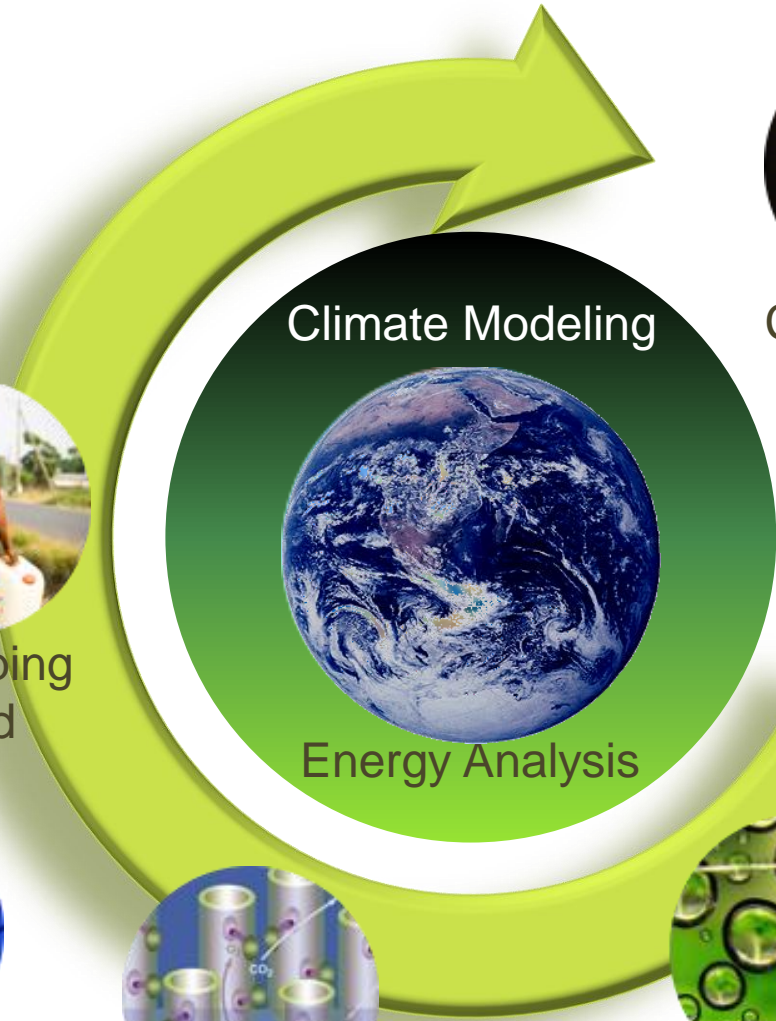
# Berkeley Lab Research Strengths



Efficiency



Combustion



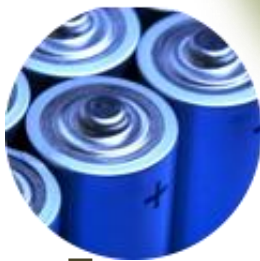
Carbon Capture & Storage



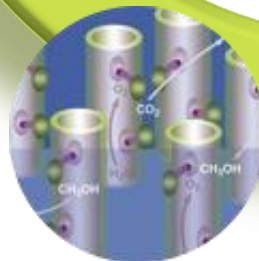
Developing World



Photovoltaics



Energy Storage



Artificial Photosynthesis



Biofuels

# Carbon Cycle 2.0 Key Components

## Featured capabilities & programs

1. JBEI: bioenergy institute (+
2. JCAP/SERC: artificial photosynthesis
3. Carbon Capture & Storage
4. Climate modeling & Energy Analysis
5. US-China CERC in Bldg. Efficiency

## Developing Initiatives & Opportunities

1. Biological soil system science
2. Efficient combustion (new FY12 \$\$)
3. Energy for Developing World
4. Energy storage (FY12 Hub)
5. Critical Energy Materials (FY12 Hub)
6. Smart/Efficient Grid (Hub +\$20M)

## Key Research Facilities



Advanced Light  
Source -> NGLS



National Energy Research  
Scientific Computing Center



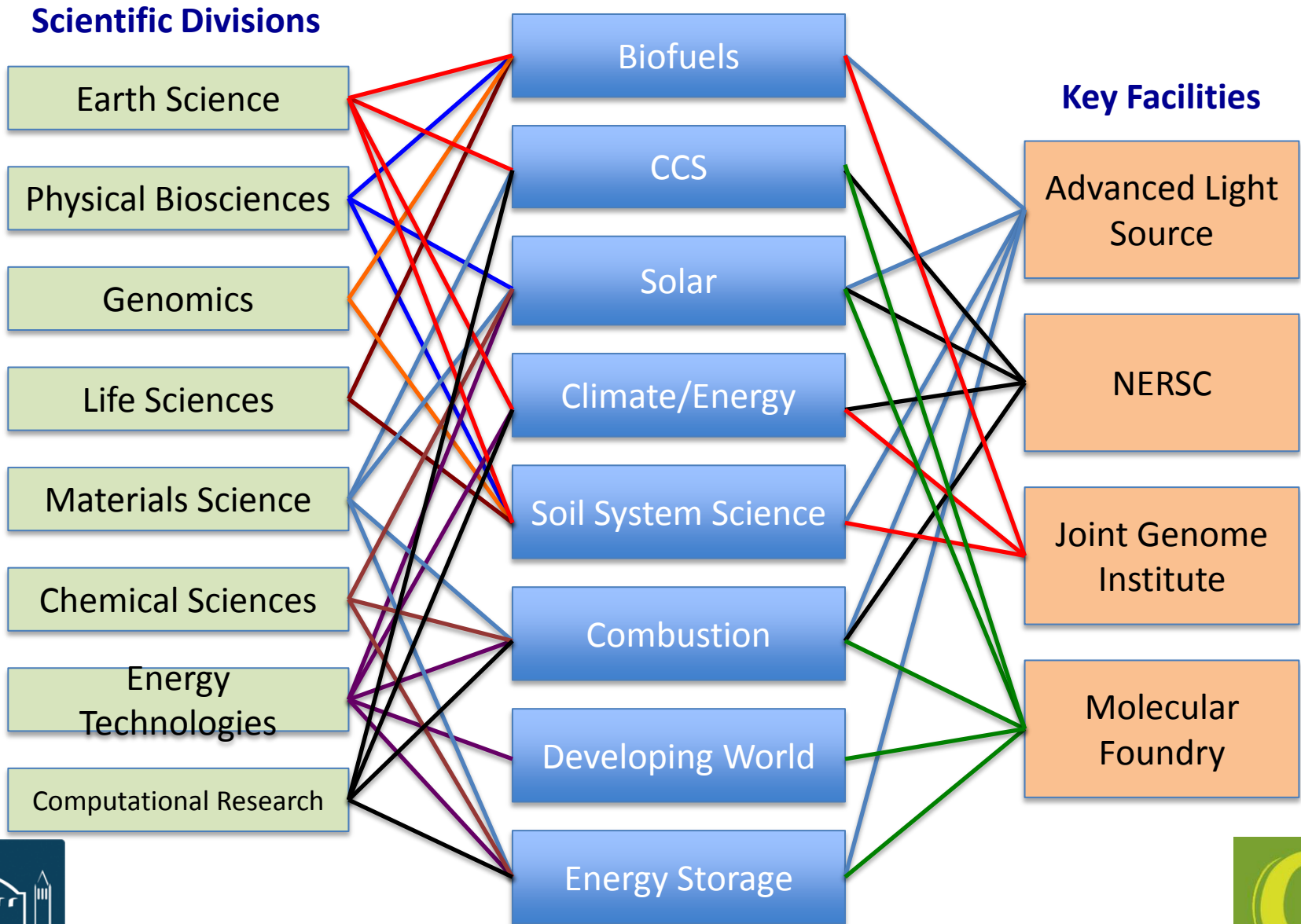
Joint Genome Institute



Molecular Foundry



# CC2.0 Research: Divisions & Facilities Involvement



## Recent additions to the Energy/Environment Research Portfolio

- JBEI: one of 3 DOE Bioenergy Research Centers (2008)
- Two Energy Frontier Research Centers (2009)
  - Gas phase separations for carbon capture
  - Nanoscale controls on geologic CO<sub>2</sub> (carbon storage)  
*(w/other support from DOE, ca. \$20M/yr in CCS research)*
- National User Facility for Net-Zero Energy Buildings (2009)
- JCAP: DOE Energy Innovation Hub (2010)
  - Artificial photosynthesis; collaboration w/Caltech
- US-China Clean Energy Research Center (CERC) (2010)
  - Buildings energy efficiency (w/several partners)
- New funding from Technology programs (2009 – 2011)
  - EERE, Fossil Energy, Nuclear Energy, EM



## New and developing Initiatives for CC2.0

### ***Biosequestration/Ecogenomics Center***

Advance understanding of microbial community processes and feedbacks in dynamic ecosystems; environmental 'omics through soil processes, phylogenetics, synchrotron imaging, climate change feedbacks

### ***Institute/Center for CCS***

Amalgamate our efforts in Capture and Sequestration (now ca. \$20M/yr) and seek a higher profile for our work. Would combine funding from FE and BES (plus ARPA-e). Discussions have begun on a path forward.

### ***Center for (Integrated Earth System Modeling/Energy Analysis/Integrated Assessment)***

Understanding the environmental, economic and climate impacts of new and prospective energy technologies and climate change mitigation strategies. Four LDRD projects funded in FY11 are primers.



## Potential Funding Opportunities for FY12\*

- **Batteries/Energy Storage Hub (BES; \$34M)**
  - Preparing for a Hub competition as a partner, with Argonne as lead
- **Combustion (BES & EERE; \$20M)**
  - Collaboration with SNL/Livermore in the area of internal combustion engines. Also starting discussions with NETL on issues related to combustion for electric power generation and to lower the cost of CO<sub>2</sub> capture
- **Critical Energy Materials Hub (EERE; \$20M)**
- **Smart Grid Technology and Systems Hub (EERE; \$20M)**
- **Advanced Modeling Grid Research (EERE; \$20M)**

\*included in President's FY12 Budget

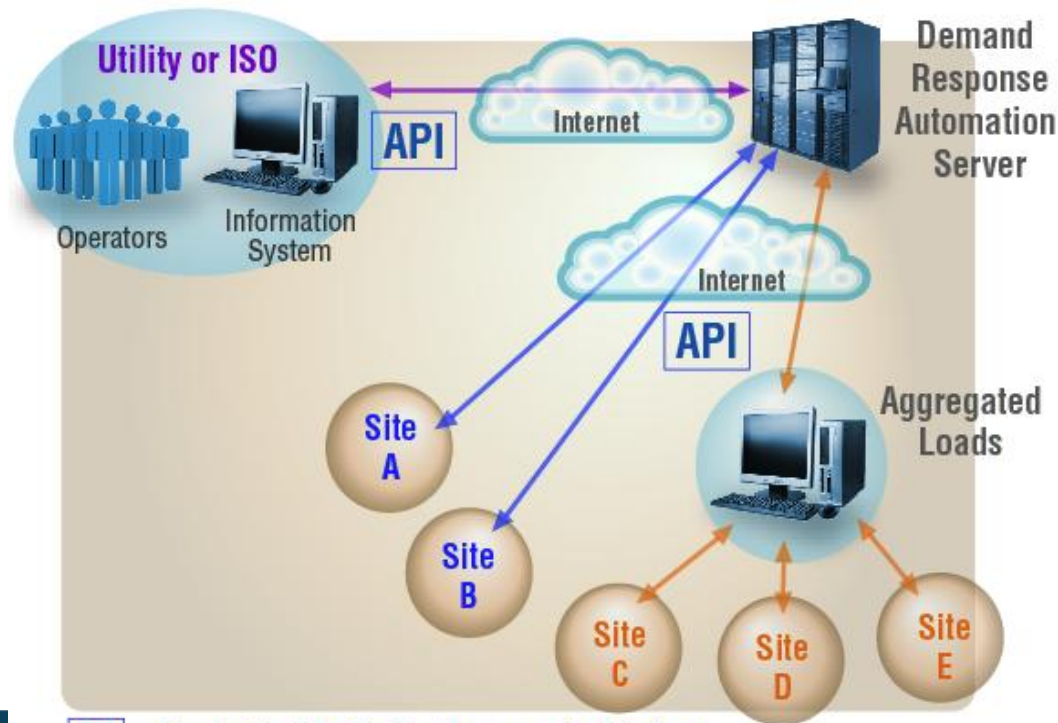


# Energy Storage Hub Basics

- Funded and managed by DOE Office of Basic Energy Sciences
  - FY12 request is \$34.02M
- **Premise:** Low energy density and high cost prevent widespread use of batteries in transportation and grid applications
  - Estimates suggest that a 2-5x increase in energy density and a 3-5x reduction in cost is essential.
- **Focus:** Explore fundamental limitations that prevent batteries from reaching theoretical limits:
  - Why is the electrochemical stability window of known electrolytes limited to 3.3V? Can this be increased to 5 V?
  - Why is the practical energy density of a battery 50% of the theoretical energy density? Can this be increased to 90%?

# EETD's Demand Response Research Center (DRRC)

- The DRRC has developed a new grid signaling system that has been deployed in California and used around the world.
- OpenADR is an open API signaling system to automate DR through embedded clients allowing continuous, low-cost automation



API = Standardized Application Programming Interface

**Signaling**- continuous, 2-way, secure messaging system for dynamic prices, emergency and reliability signals. One-way applications are under development

**Client-server architecture** - uses open interfaces to allow interoperability with publish and subscribe systems

**Current system** - uses [internet](#) available at most large facilities or broadcasting points.

**Hardware retrofit or embedded software** - many clients fully implemented with existing XML software

PI: M.A. Piette, LBNL

# CC2.0 progress and metrics

- Initiative taking shape, progress on many fronts
- LDRD and seminar series are being effective at stimulating cross-disciplinary interaction
- Management structure is developing, needs further definition
- Industry Advisory Board may be critical; aim for May/June launch
- Enthusiastic support across the Lab
- Defining success will be important....
  - New multi-divisional research efforts
  - Programs that span basic and applied DOE offices
  - Changes to our external image
  - Increased patent and license activity in energy/environment

