Presentation to State Energy Advisory Board (STEAB)
February 22, 2011

Building Controls and Lighting Systems

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U.S. Building End Use Energy Consumption

Building sector has:

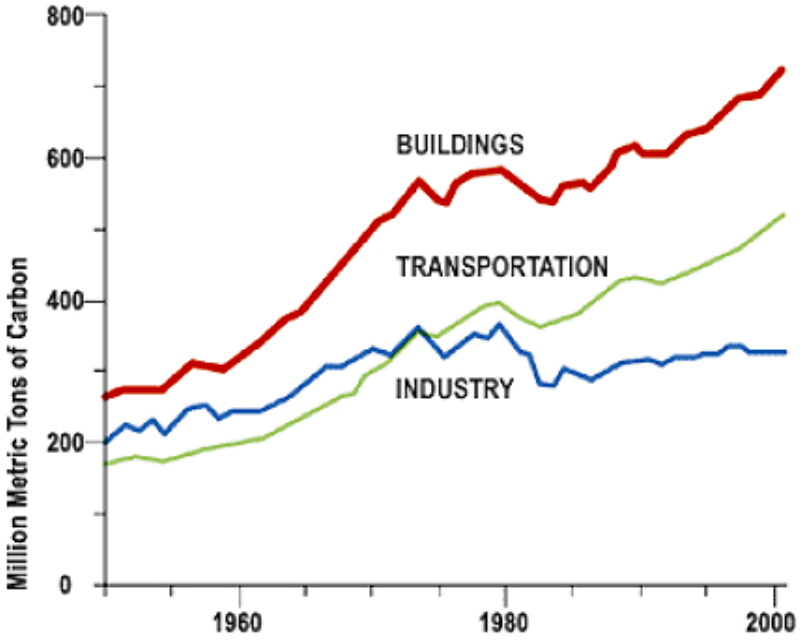
Largest Energy Use!

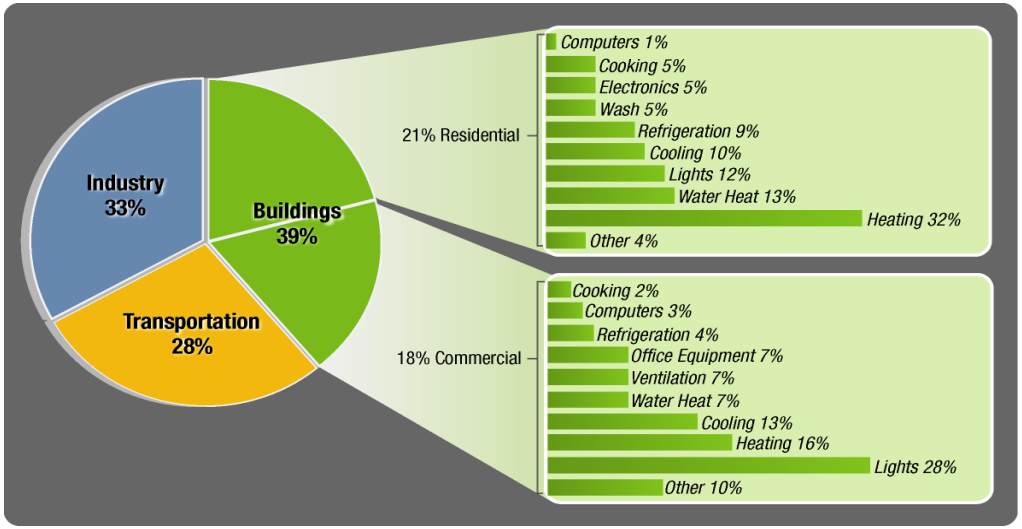
Fastest growth rate!

Buildings consume 40% of total U.S. energy

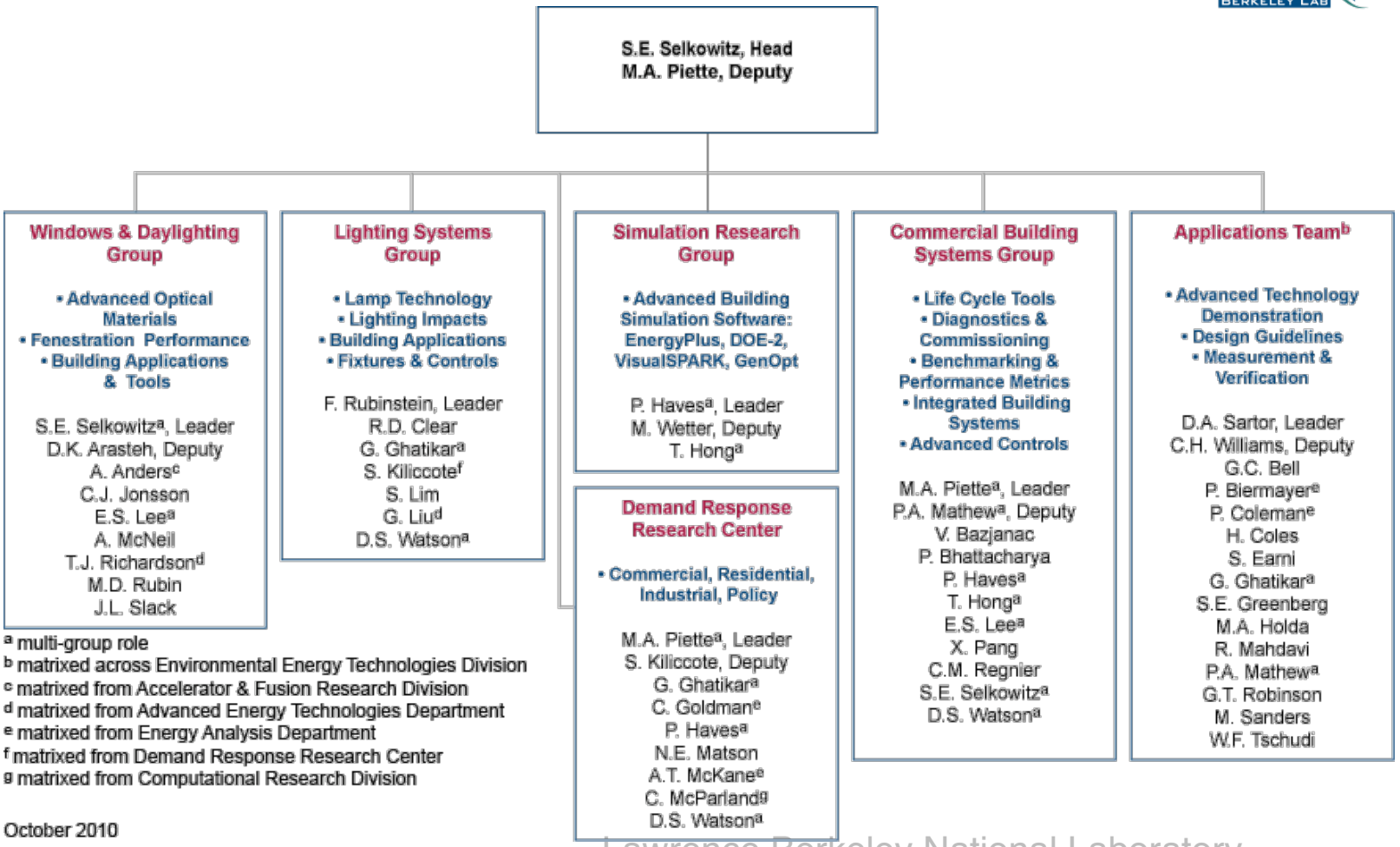
- ***71% of electricity***
- ***54% of natural gas***

No Single End Use Dominates





Building Technologies Department



[a] multi-group role
[b] matrixed across Environmental Energy Technologies Division
[c] matrixed from Accelerator & Fusion Research Division
[d] matrixed from Advanced Energy Technologies Department
[e] matrixed from Energy Analysis Department
[f] matrixed from Demand Response Research Center
[g] matrixed from Computational Research Division

October 2010

RDD&D Topics in Building Technologies Dept.

A. Building Systems

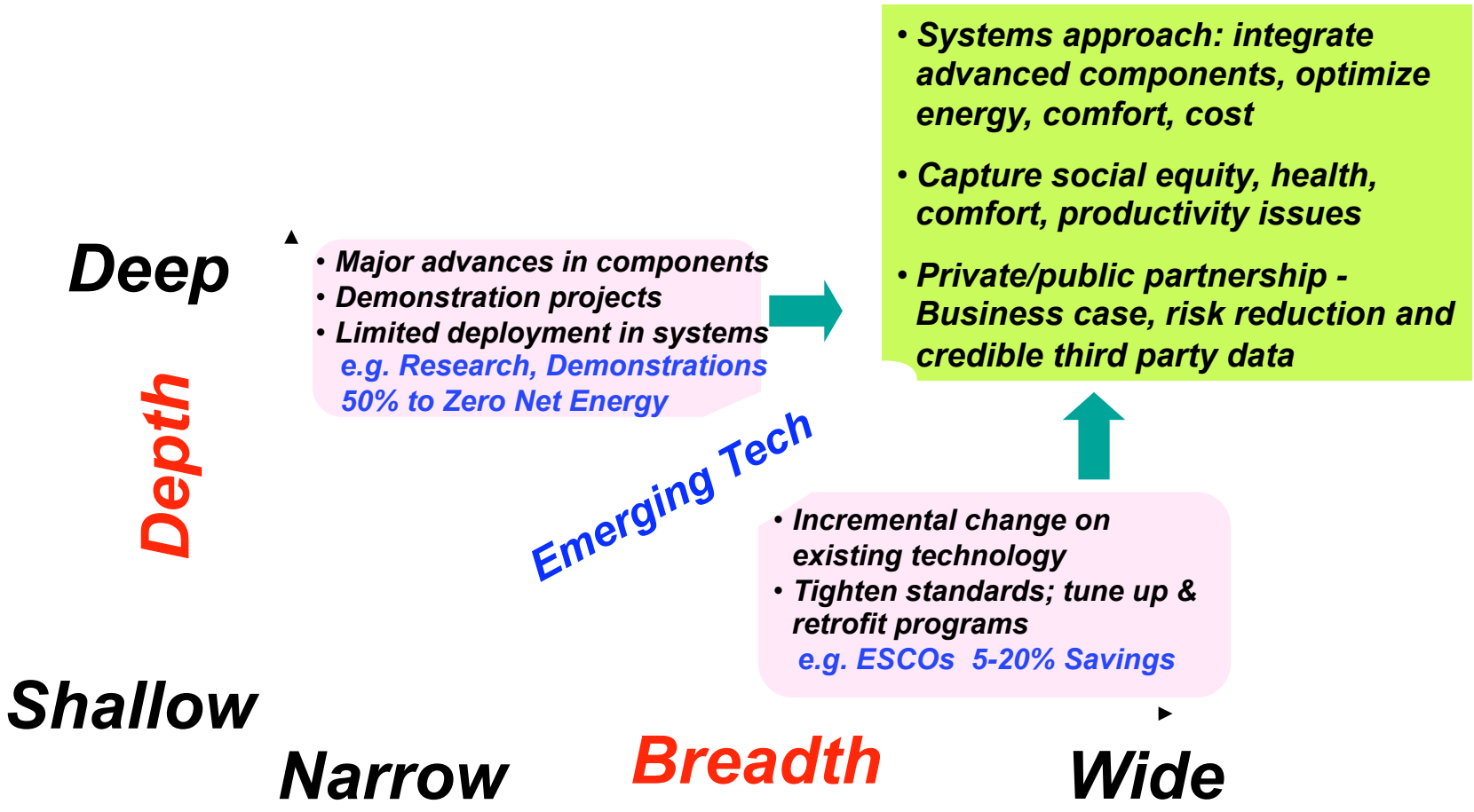
- Windows, Facades, and Daylighting
- Lighting Controls
- Low-energy cooling and controls
- Wireless sensor networks

B. Design, Delivery, and Operations

- Simulation Tools and Methods
- Building Information Modeling and interoperability
- Fault Detection and Diagnostics
- Optimized controls and commissioning
- Demand response/Smart Grid
- Benchmarking, rating, and labeling
- Energy information systems
- Health, Comfort Impacts

C. Deployment and Market Engagement

- Demonstration and technical assistance
- High-tech buildings
- Alternative financing and valuation
- Measurement & verification
- Training tools and curricula
- Stock modeling and forecasting
- Programs, policies, codes


Deep
Depth
• Major advances in components
• Demonstration projects
• Limited deployment in systems
e.g. Research, Demonstrations
50% to Zero Net Energy
• Systems approach: integrate advanced components, optimize energy, comfort, cost
• Capture social equity, health, comfort, productivity issues
• Private/public partnership - Business case, risk reduction and credible third party data
Emerging Tech
• Incremental change on existing technology
• Tighten standards; tune up & retrofit programs
e.g. ESCOs 5-20% Savings
Shallow
Narrow
Breadth
Wide

Buildings "Grand Challenge"

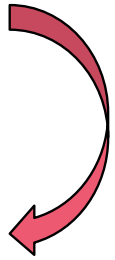
- Focus on Life Cycle of the Building
  - — Design → Construction → Operations → Decommissioning
- Focus on Integrated Smart Building Systems
  - — Materials → Devices → Integrated Systems → Buildings
- Focus on "intersection" of Technology and Policy
  - — Innovative, Disruptive technologies
  - — Occupant behavior, life style, satisfaction, comfort
  - — Investment and Decision making
- Focus on Measurable, Documented Energy Impacts
  - — Make performance visible and understandable

Strategy for Achieving "Very Low Energy" Buildings

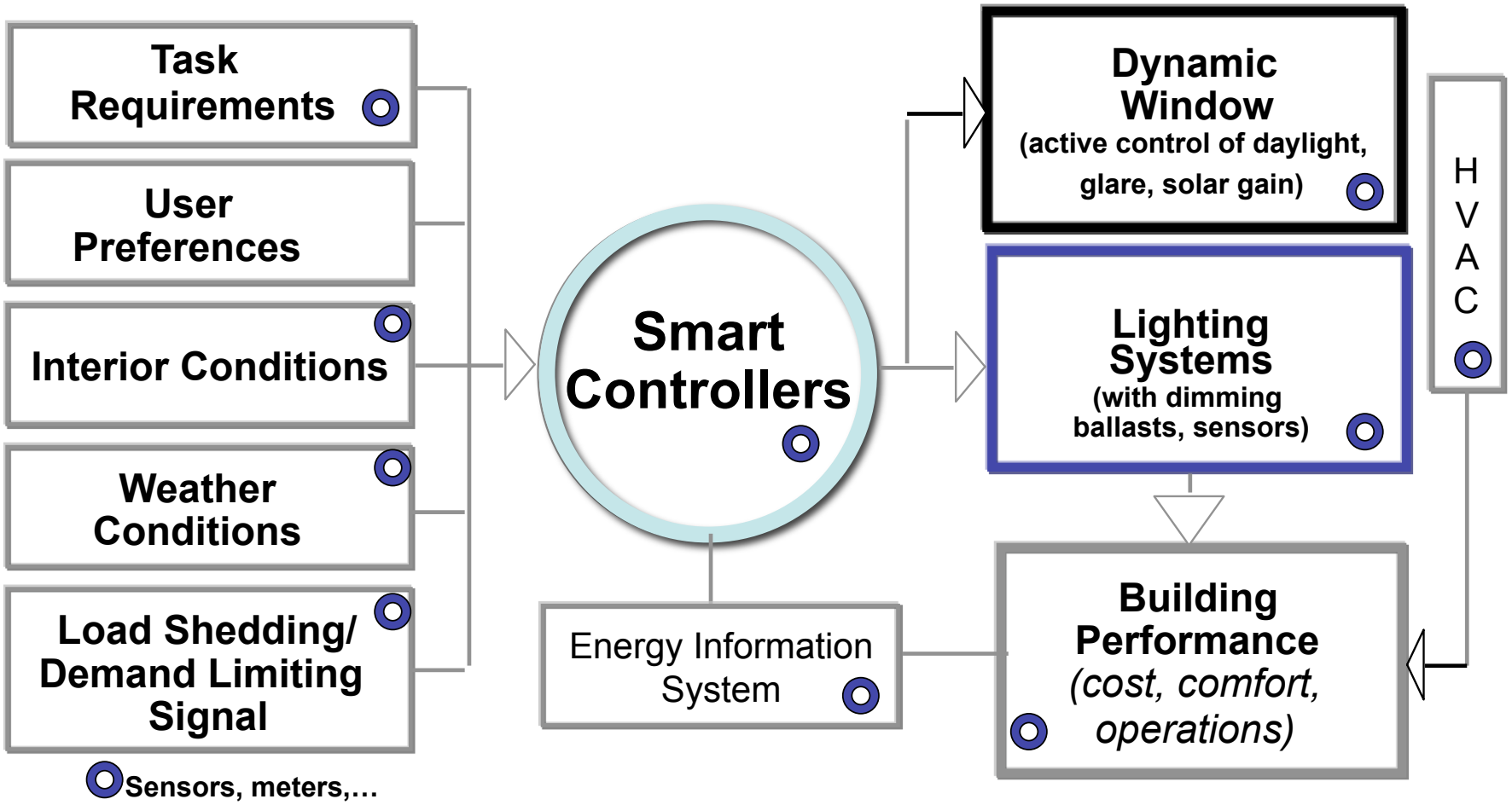
Market Forces

- **Deployment: (5-30% savings)**
  - — Identify what works and deploy it widely
  - — Applies to all buildings: new and existing
  - — Mandatory programs: codes and standards
  - — Voluntary programs: incentives
- **Demonstrate <u>Emerging Solutions</u> (20-60% savings)**
  - — Find underutilized, unproven technologies and systems
  - — R&D to improve, optimize; make them mainstream
- **R&D --> Breakthrough Innovations (50-80% savings plus on-site renewable power)**
  - — New, more effective, high performance, integrated systems options
  - — Technology, Systems, Process
  - — Lower costs, lower risk

Feedback



Exploring Intelligent Control Systems

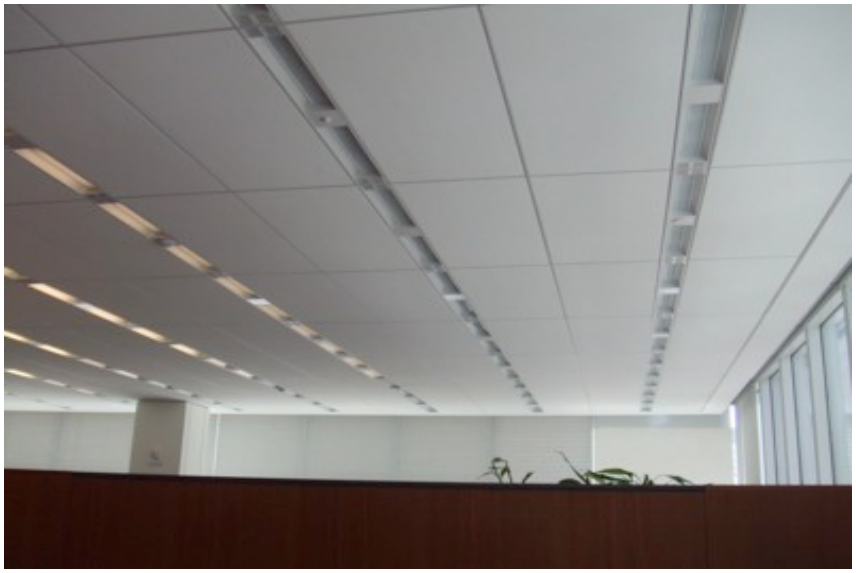


Intelligent Lighting and Shade Control

New York Times HQ

Occupied 2007

- Dimmable lighting
  - Addressable
  - Affordable (1/3 original cost estimate)
  - Multifunctional
- Automated Shading
  - Cooling load control
  - Glare control



New York Times office with dimmable lights and automated shading

Lighting wastes energy because dimming lighting controls are not widely used

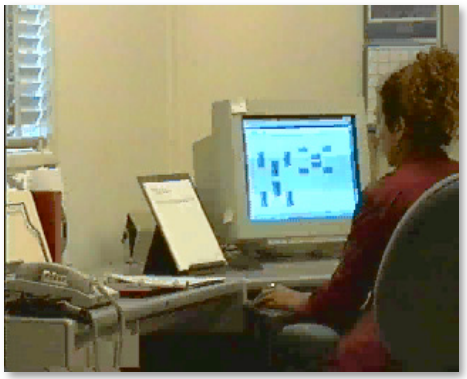
All Lighting Should be:

- ***Dimmable***
- ***Addressable***
- ***(Affordable)***

Major Lighting Control Strategies

Vacancy Detection or Scheduling
Automatic Dimming with Daylight
Tuning Strategies
- **Personal dimming controls**
- **Institutional requirements**

Lumen Maintenance
Demand Response



Lighting and Daylighting Control in Commercial Buildings

Problem Lighting energy is wasted when space is unoccupied and daylight is available – improved control needed

Projects

1980 – 2000 *Electronic ballasts and analog lighting controls*	2000 – 2010 *Digital lighting controls*	2010 – future *Wireless*
1979: PG&E Bldg	2002: Ron Dellums Bldg	2010: Seven GSA sites in CA & NV
1981: World Trade Center	2008: NY Times Bldg	2010: Ft. Irwin (US Army)
1982: VA Hospital	2009: Philip Burton Bldg	2012 - : User Facility Testbeds
1991: Watergate Bldg		
1996: Philip Burton Bldg		

1. **Measure lighting energy consumption under different operating scenarios**
   - Power meters installed on selected circuits
   - Detailed analysis of lighting control system data
2. **Document lighting conditions under different conditions**
   - Standard photometric surveys
   - High dynamic range (HDR) photometry
3. **Evaluate user acceptance with occupant surveys**

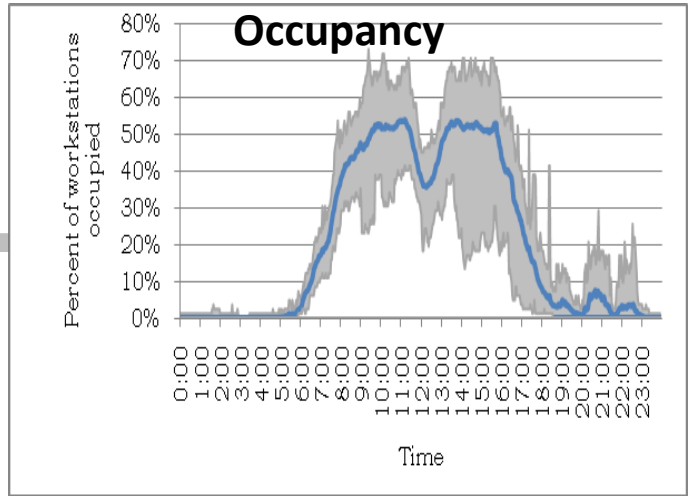
Smart Controls Retrofit Options

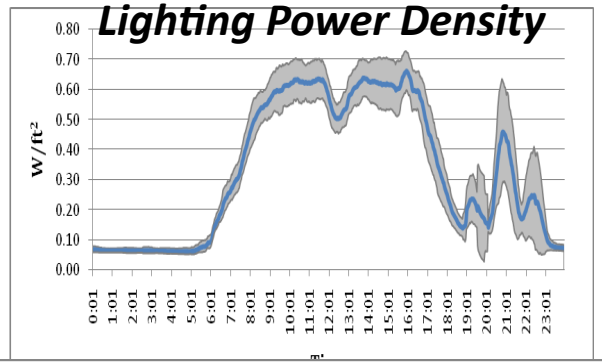
GSA Retrofit - Conventional

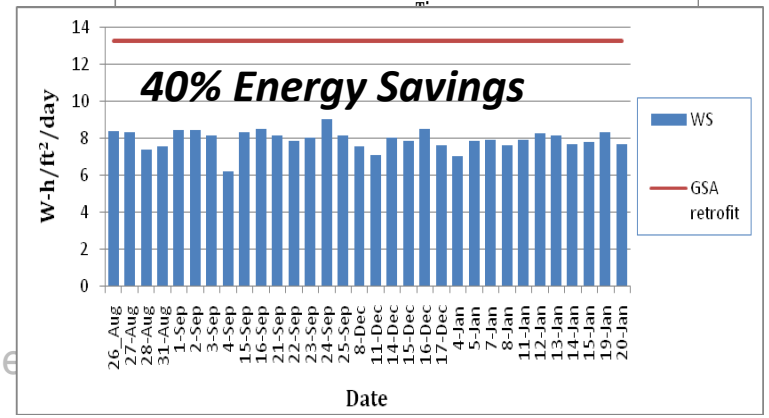
- *Continuous rows of fixtures*
- *0.83W/ft² installed*
- *Switching at room level only*
- *Long operating hours (16 hours/day)*
- *No personal control*

Workstation-Specific

- *3 lamps/fixture*
- *1.23W/ft² installed*
- *0.97W/ft² default*
- *30 minute timeouts*
- *Indirect personal control*
- *Photocells not activated*







The workstation-specific lighting system has an actual LPD far lower than the installed LPD (1.23W/ft²) and the baseline LPD (0.83W/ft²) throughout the day.

40% savings vs "better than code compliant LPD"

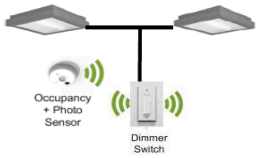
Scaling Up Installation of Workstation Lighting

Technology Description

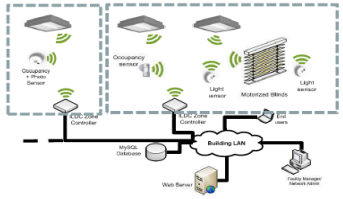
	OccuSwitch Wireless	Wired PNLCS	Hybrid ILDC
System architecture	Room-based control	Distributed control bldg-wide connectivity	Room/area based control with building-wide connectivity
Supported Sensors	Light sensors and occupancy sensors	Ceiling mounted light and occupancy sensors	Sunlight intensity sensor, light/occupancy/temp sensors
Scalability	Room by Room	Scalable from a single room to entire building	Scalable from a single room to wide area control
Best applications	Single offices; barracks; Retrofits; smaller budget	New construction, major renovation	Multi floor office buildings with daylight areas. Retrofit or new
In-room Connectivity	Wireless based on ZigBee PRO standard	Wired	Wireless based on ZigBee PRO standard
Cost advantage	+++ Installation ++ Commissioning	+ Installation +++ Commissioning	++ Installation ++ Commissioning
Energy adv.	++	++	+++

ESTCP

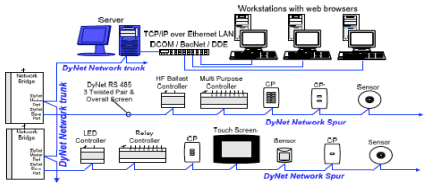
OccuSwitch Wireless



Hybrid ILDC



PNLCS/Dynalite



Kit of Parts

Wired
Wireless
RF, IR, Light
Powerline carrier

Dimmable
Addressable
Local and Central Control
Multiple Strategies

Testing Advanced Lighting Controls at Ft. Irwin

w/ Philips Lighting/ESTCP project

2007 Pilot

15 cubicles

1500 ft^2 measured

2009 Full Test

86 cubicles

9000 ft^2 measured

2010 – 2012 CBP sites

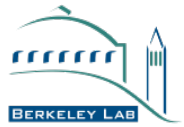
Seven sites

Over 2500 cubicles

250,000 ft^2 measured

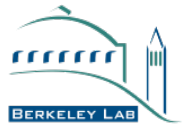
2.5 Million ft^2 affected

DOE Commercial Building Partnership Program Overview



- CBP seeks to develop a set of energy-efficient, market-ready building solutions that will be widely deployable throughout the commercial building sector
- Pilots launched in 2008, ARRA funded projects in 2010
- 54 building projects currently underway between LBNL, PNNL and NREL
  - Projects include retail, commercial/office, higher education/institutional, high rise multi family, etc.
  - Complete list: http://www.energy.gov/news/9838.htm
- Aims to reduce energy use in the commercial building sector by demonstrating high performance design, construction, and operations options that can be widely deployed throughout the commercial building sector
  - Lab researchers work with outside Technical Expert Teams and M&V Technical Contractors to achieve project energy goals

CBP Project Types

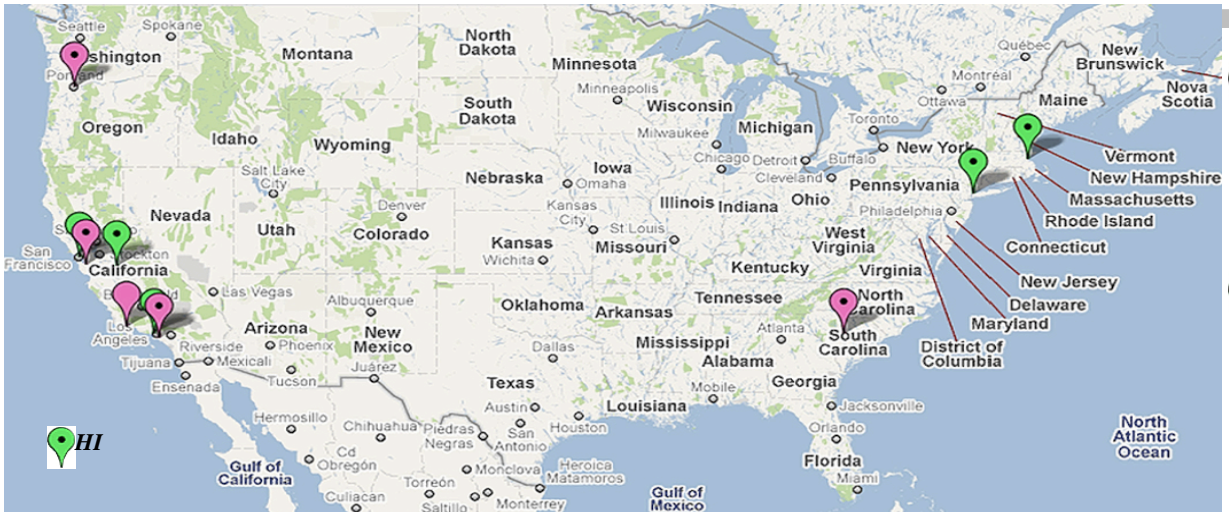


- Retrofit an existing building to achieve 30% savings compared with its baseline/CBECS energy consumption
- New building that uses 50% less energy than an ASHRAE/IESNA Standard 90.1-2007
- Retrofit two or more building systems throughout the Participant's building portfolio to achieve significant energy savings portfolio wide
- Retrofit an existing building or group of buildings (e.g., an existing campus) to achieve a 50% energy savings relative to either the median energy performance of the company's building stock or CBECS
- Design, construct, and commission a new building or group of buildings that achieve(s) net zero energy use
- At LBNL: 11 Projects underway, 6 Retrofit, 5 New Construction

DOE CBP Outcomes and Deliverables

- Development of low energy 'toolkits', products that demonstrate the techniques used to achieve the aggressive energy savings, e.g.:
  - Calculators
  - Best practice guides
  - How-to handbooks
  - Methodologies used (e.g. Cx, M&V)
  - Business cases for EEMs used
  - Technical case studies for EEMs
  - Deployment and implementation plans for Partners
- Other deliverables
  - M&V data at EEM level pre- and post- retrofit, up to 18 months, M&V reports
  - Calibrated energy models
- Deployment through Partner portfolios, CBEA, other stakeholders (e.g. utilities involved in projects)

LBNL CBP Project Locations

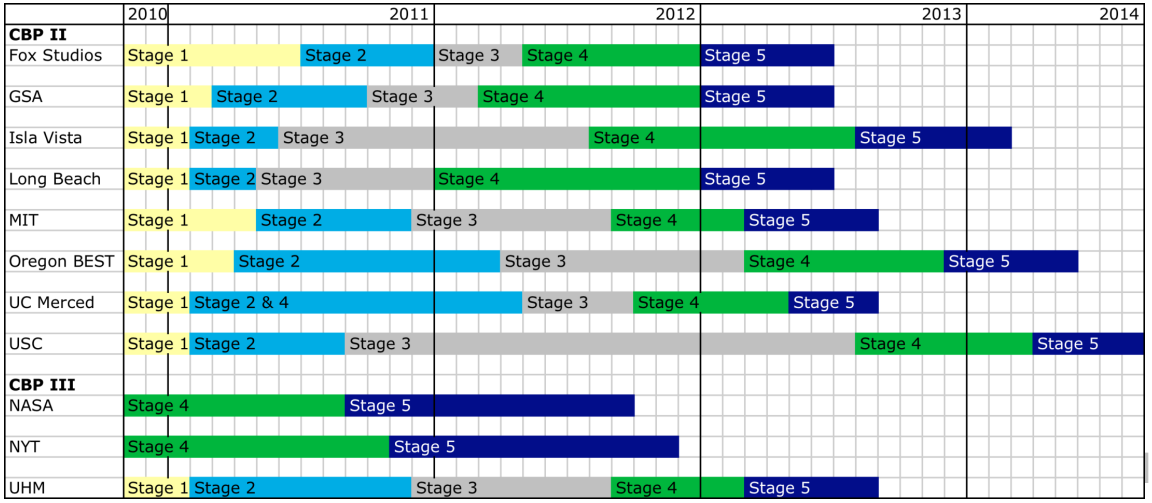


NEW CONSTRUCTION

Long Beach Gas and Oil – Long Beach, CA
Mesa Lane Partners – Isla Vista, CA
NASA Ames – Mountain View, CA
Oregon BEST – Portland, OR
University of South Carolina – Columbia, SC

RETROFITS

GSA Pacific Rim, Region 9 – San Francisco, CA
Massachusetts Institute of Technology – Cambridge, MA
New York Times Building – New York, NY
Twentieth Century Fox Studios LA – Los Angeles, CA
University of California at Merced – Merced, CA
University of Hawai'i at Manoa – Honolulu, HI



MIT, Boston, MA

- Building size: 36,000 sf data center and 463,000 sf Stata building
- Portfolio size: ~12 million sf
- Potential market impact: Universities across US
- Project type: retrofit of two buildings for significant portfolio savings; Data Center (HVAC and lighting) and Stata Center (Lighting and Server Room HVAC
- Utility partner: NSTAR
- Deliverables
  - Case studies expected in 2013
- **Outcomes**
  - **Replicable lighting controls strategies for the campus**
  - **Qualitative lighting quality surveys**
  - **Replicable strategies for reducing energy consumption in data centers**
  - **May be ISO 50001/GSEP Pilot project**

University of South Carolina, SC

Innovista Research Park

- Building size: 250,000 sf
- Portfolio size: ~11 million sf
- Potential market impact: Universities across US through American College and University President's Climate Commitment
- Project type: new construction, Net zero energy goal, minimum 50% energy savings relative to ASHRAE 90.1-2007
- Deliverables
  - Case studies expected in 2014
- **Outcomes**
  - **Aggressive low energy building systems and strategies**
  - **Measure, compare and analyze occupant productivity in new building; compared to current building**
  - **Engaging and educating Partner and PDT on low-energy design**

University of California, Merced, CA

- Building size: 237,000 sf
- Portfolio size: 780,000 sf
- Potential market impact: Universities throughout CSU, UC system, etc.
- Project type: retrofit multiple building systems for significant portfolio savings; Campus Central Heating plant and 2 System retrofits in Science and Engineering Building
- Deliverables
  - Case studies in 2013
  - Key performance metrics
- **Outcomes**
  - **Improve and expand the Energy Performance Platform (EPP) and use this energy information system to track performance and identify areas of retrofit and energy saving opportunity**
  - **Determine key performance metrics for energy consumption**

The LOOP, Santa Barbara, CA

- Building, portfolio size: 50,000 sf
- Potential market impact: University dormitories in CSU, UC systems, etc.
- Project type: new construction, min. 50% below ASHRAE 90.1-2007
- Utility partner – Southern California Edison, Emerging Technologies
- Deliverables
  - Case studies in 2014
  - Submetering case study
- **Outcomes**
  - **Passive cooling and ventilation, phase change wallboard**
  - **Solar hot water heating and submetering strategies**
  - **Low-energy commercial kitchen HVAC strategies**

GSA Region 9, CA & NV

- Building size: 100,000–500,000 sf
- Portfolio size: 350 million sf
- Potential market impact: Government buildings across US
- Project type: retrofit of 10 buildings for significant portfolio savings; Lighting and HVAC at zonal level
- Deliverables
  - Case studies in 2013
  - Lighting design analysis tool (CBEA collaboration)
- **Outcomes**
  - **Occupancy based lighting controls strategies and benefits for workplace environment**
  - **Occupancy based HVAC controls strategies and benefits**
  - **Comparison of retrofit strategies across climate zones**

Oregon BEST, Portland, OR

- Building size: 200,000 sf
- Portfolio size: 200,000 sf
- Potential market impact: Commercial offices, classrooms
- Project type: new construction, Living Building Challenge (Triple Net Zero), min. 50% below ASHRAE 90.1-2007
- Deliverables
  - Case studies in 2014
- **Outcomes**
  - **Aggressive, but cost effective, net zero building strategies**
  - **Strategies for individualized monitoring plans**
  - **Methodology to motivate energy-saving behavior**
  - **Strategies for meeting the Living Building requirements**

Fox Studios, Los Angeles, CA

- Building size: 31,000 sf, 14,000 sf
- Portfolio size: 1.2 million sf
- Potential market impact: Large open spaces (e.g., warehouses) and other studio settings
- Project type: retrofit of 2 buildings and central plant for significant portfolio savings
- Deliverables
  - Case studies in 2013
- **Outcomes**
  - **Chilled water plant energy reduction strategies**
  - **Replicable strategies for alternative HVAC systems on the campus**

Long Beach Gas and Oil Building, Long Beach, CA

- Building size: 20,000 sf
- Portfolio size: ~1 million sf
- Potential market impact: Office buildings and small commercial spaces throughout the City of Long Beach
- Project type: new construction, 50% below ASHRAE 90.1-2007
- Deliverables
  - Case studies in 2013
- **Outcomes**
  - **Replicable strategies for low-energy small offices in Long Beach**
  - **Strategies for daylighting in Long Beach**
  - **Strategies for low-energy modular construction**

University of Hawaii at Manoa, HI

- Building size: 80,000 sf
- Portfolio size: 8 million sf
- Potential market impact: 8-campus UH system; natural ventilation strategy to serve as a model for other campuses
- Project type: retrofit; minimum 30% below current energy consumption, Net Zero Energy goal
- Deliverables
  - Case studies expected in 2013
- **Outcomes**
  - **Advanced thermal comfort standards for Hawaii climate**
  - **Strategies for passive and natural ventilation in campus buildings**
  - **Strategies for reducing plug loads in campus buildings**
  - **Strategies for maintaining occupant comfort in a daylight and naturally ventilated space**

NASA Ames, Moffett Field, CA

- Building size: 50,000 sf
- Portfolio size: 5 million sf
- Potential market impact: large commercial office buildings; advanced controls strategies and technologies could be employed in all office buildings
- Project type: commissioning of advanced building controls in a new building
- Deliverables
  - Case studies in 2012
- **Outcomes**
  - **Methodology for creating a BIM model that can be used for continuous performance monitoring, O&M**
  - **Replicable strategies for advanced building controls, including FDD, in office buildings**

New York Times HQ, NYC

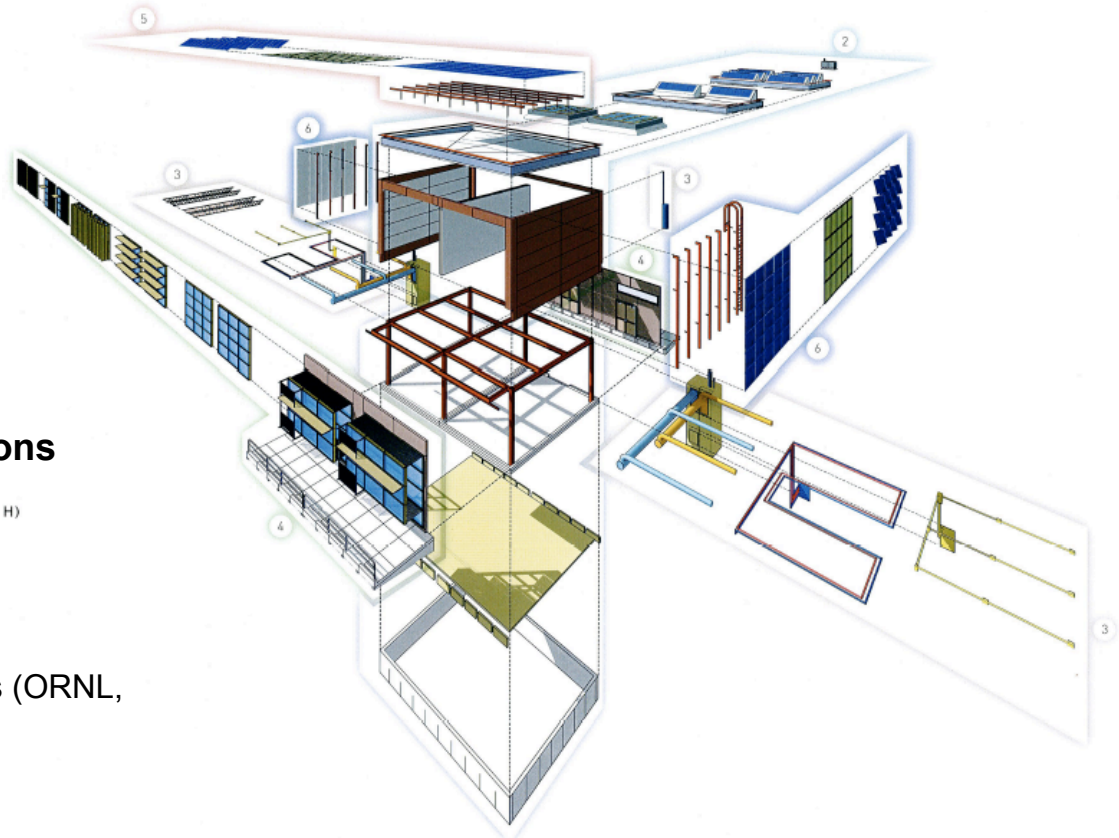
- Building size: 1.6 million sf
- Portfolio size: 1.6 million sf
- Potential market impact: large commercial office buildings; Daylighting, shading, UFAD can be used in all office buildings
- Project type: measure performance of dynamic shading, lighting, and UFAD HVAC systems
- Related work by NYSERDA
- Deliverables
  - Post-occupancy evaluation under way now
  - Case studies in 2012
- **Outcomes**
  - **Measured energy and demand savings will promote broader adoption in market**
  - **Quantified impact of shading on cooling loads and comfort**
  - **Documented occupant comfort as a result of daylighting and shading technologies**

LBNL National User Testbed Facility

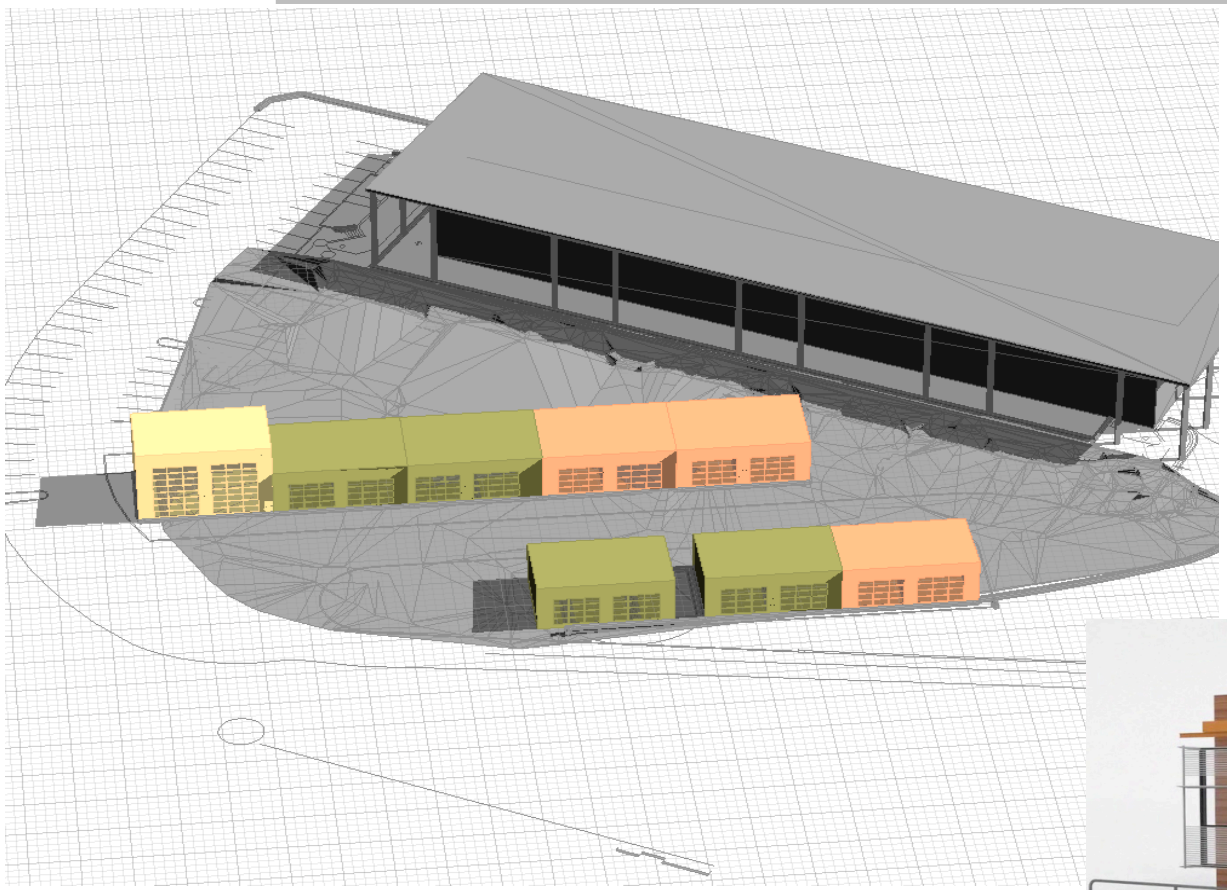
- **Design Underway for User Testbed Facility**
  - Multiple comparative experiments
  - Experimental data sharing
- **6 to 8 Testbeds - Integration studies, exploring interactions in low-energy building solutions**
  - System or component level research
  - Dynamic envelope control, lighting, daylighting
  - Interactive effects of process loads
  - Flexible room-side thermal systems, e.g. VAV, radiant, UFAD,…
  - Integrated Systems Optimization
  - Simulation tool validation
  - Studies on comfort factors including glare, thermal distribution, operative temperature
  - 2- story high bay space for lighting, skylights
  - Sensors and Controls integration Lab
  - Design/Visualization Lab

LBNL National User Testbed Facility

- **Reconfigurable Test Modules**
  - Structure
  - Façade/Glazing/Shading
  - Roof/Skylights
  - Interior space – Ceiling, floor
  - HVAC
  - Lighting
- **Developing Management and Operations plans**
- **Nucleus for National Network of Test facilities**
  - Interface with public and private test sites (ORNL, NREL, Iowa Energy Center, utilities, etc.)
  - Link and share data sources



LBNL National User Testbed Facility



Design: 2011
Construction: 2012
Operations: 2013