Building Controls and Lighting Systems

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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

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Building Technologies Department

S.E. Selkowitz, Head
M.A. Piette, Deputy

Windows & Daylighting Group
- Advanced Optical Materials
- Fenestration Performance
- Building Applications & Tools
  S.E. Selkowitz, Leader
  D.K. Arasteh, Deputy
  A. Anders
  C.J. Jonsson
  E.S. Lee
  A. McNeil
  T.J. Richardson
  M.D. Rubin
  J.L. Black

Lighting Systems Group
- Lamp Technology
- Lighting Impacts
- Building Applications
- Fixtures & Controls
  F. Rubinstein, Leader
  R.D. Clear
  G. Chatkar
  S. Kilicote
  S. Lim
  G. Liu
  D.S. Watson

Simulation Research Group
- Advanced Building Simulation Software: EnergyPlus, DOE-2, VisualSFARK, GeoOpt
  P. Haves, Leader
  M. Wetter, Deputy
  T. Hong

Commercial Building Systems Group
- Life Cycle Tools
- Diagnostics & Commissioning
- Benchmarking & Performance Metrics
- Integrated Building Systems
- Advanced Controls
  M.A. Piette, Leader
  P.A. Mathew, Deputy
  V. Bazjanac
  P. Bhattacharya
  P. Haves
  T. Hong
  E.S. Lee
  X. Pang
  C.M. Regnier
  S.E. Selkowitz
  D.S. Watson

Demand Response Research Center
- Commercial, Residential, Industrial, Policy
  M.A. Piette, Leader
  S. Kilicote, Deputy
  G. Chatkar
  C. Goldman
  P. Haves
  N.E. Mason
  A.T. McKane
  C. McFarland
  D.S. Watson

Applications Team\(^b\)
- Advanced Technology Demonstration
- Design Guidelines
- Measurement & Verification
  D.A. Sator, Leader
  C.H. Williams, Deputy
  G.C. Bell
  P. Biermayer
  P. Coleman
  H. Coles
  S. Earni
  G. Chatkar
  S.E. Greenberg
  M.A. Holda
  R. Meshadi
  P.A. Mathew
  G.T. Robinson
  M. Sanders
  W.F. Tschudi

\(^a\) 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

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Scale and Impact: Approaches to Achieve Sector-wide Efficiency Goals?

Deep

- 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

Shallow

- Major advances in components
- Demonstration projects
- Limited deployment in systems e.g. Research, Demonstrations 50% to Zero Net Energy

Depth

- Incremental change on existing technology
- Tighten standards; tune up & retrofit programs e.g. ESCOs 5-20% Savings

Breadth

Narrow

- Emerging Tech

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

- **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 Emerging Solutions (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
Exploring Intelligent Control Systems

- Task Requirements
- User Preferences
- Interior Conditions
- Weather Conditions
- Load Shedding/Demand Limiting Signal

Smart Controllers

Energy Information System

Dynamic Window (active control of daylight, glare, solar gain)

Lighting Systems (with dimming ballasts, sensors)

Building Performance (cost, comfort, operations)
Intelligent Lighting and Shade Control

New York Times HQ

- 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

Occupied 2007
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*
- 1979: PG&E Bldg
- 1981: World Trade Center
- 1982: VA Hospital
- 1991: Watergate Bldg
- 1996: Philip Burton Bldg

2000 – 2010 *Digital lighting controls*
- 2002: Ron Dellums Bldg
- 2008: NY Times Bldg
- 2009: Philip Burton Bldg

2010 – future *Wireless*
- 2010: Seven GSA sites in CA & NV
- 2010: Ft. Irwin (US Army)
- 2012 - : User Facility Testbeds

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

Testing Advanced Lighting Controls at Ft. Irwin
w/ Philips Lighting/ESTCP project

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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.
- 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

RETROPTS
- 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

- 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

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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