Photocontrols and Daylight Savings in Sidelit Spaces

Success Factors in Design and Commissioning

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Project Team

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Background

- Theoretical studies show large energy savings are possible – 25% of floorspace within 15' of a window
- No large post-occupancy studies in real buildings
- Anecdotal stories of lighting controls failure
- Previous studies:
  - SCE study of daylight controls in spaces with skylights found few failures and good energy savings
  - PG&E/PIER study of "non-energy" effects of daylight found
    - Students' test scores improved when they had more daylight
    - Workers performance on simple tasks improved when they had better views out of the building
  - Conclusive evidence of a link between short-wavelength (blue) light and human circadian system

Sidelit Photocontrol Field Study

QUESTIONS:

- How well do photocontrols systems work in conjunction with sidelighting through windows?
- What factors are associated with success and failure, and with improved performance?
  - Occupancy type
  - Control system design
  - Dimming vs. switching
  - Bldg/space design
  - Interior design
  - Energy management
  - Commissioning
  - Lighting design
  - Fenestration design
  - Luminance or illuminance levels

Four Parts to the Study

1. Find lots of daylit buildings
2. Conduct a telephone survey of site facilities managers
3. Conduct on-on-site surveys of each daylit space
4. Analyze the data

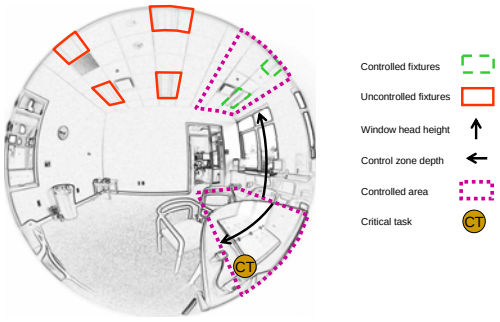
Telephone Interview Results

- 200-500 sidelit buildings with photocontrols in CA, OR and WA
- Most interviewees believed their systems were working, but
  - Their judgments of success/failure were optimistic and somewhat accurate
  - Their judgments of how much energy was being saved were *very* inaccurate
- Most interviewees were satisfied with the performance of their system

On-Site Survey Methodology

1. 20-minute interview with “site host” about building, controls, user complaints etc.
2. Collect physical data in 2-4 spaces:
   1. Dimensions and photos of the space and the windows
   2. Reflectances and transmittances
   3. Locations of photocells and luminaires
3. Measure daylight and electric light levels
4. Install loggers to record illuminance and current
5. Leave loggers in place for 2 weeks
6. Retrieve and download data

Typical survey space

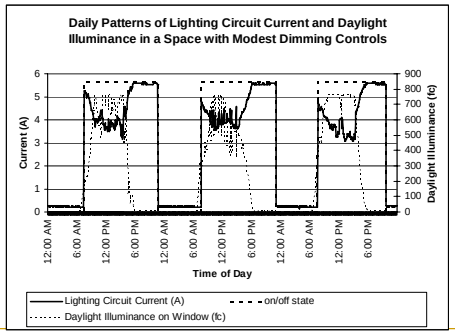


Data Logging

We left loggers in place for two weeks, taking measurements every 5 minutes:

1. Daylight illuminance inside window, facing out
2. Current (or illuminance) of electric lights
   1. Photocontrolled circuit
   2. Uncontrolled circuit
3. Critical task illuminance
4. Illuminance at photosensor

Example of Logged Data



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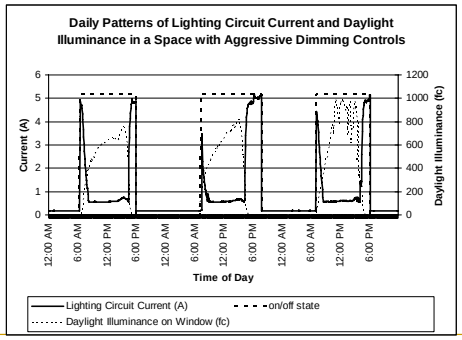

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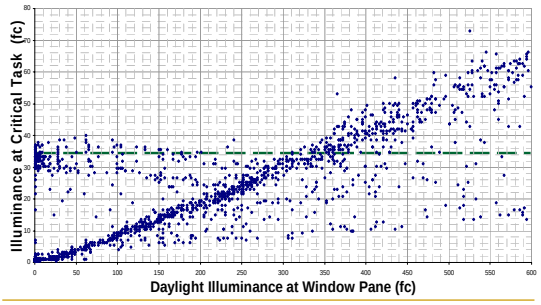

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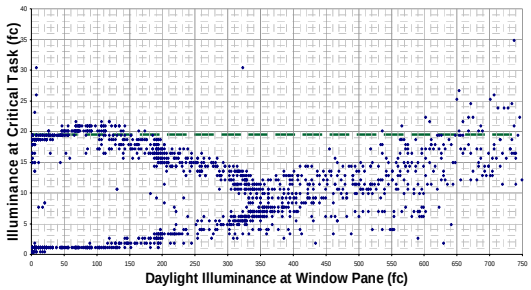


Results: Overview

- Previous toplighting study, 2003
  - 32 spaces
  - 98% net realization rate
- This study, 2005
  - 123 spaces
  - 55% were not saving any energy
  - 53% realization rate for those that were working

Site Host Interview

- Commissioning a "fuzzy' concept
  - Even if they said they had records, they could not show them to the surveyors
- 41 complaints about lighting controls:
  - 15 – too hard to calibrate
  - 6 – electric lights too dim
  - 5 – installation mistakes
  - 3 – premature lamp or ballast failures
  - 3 – occupants override system
  - 3 – not enough savings
  - 3 – trouble with blinds, glare, shadows
  - 2 – want manual overrides
  - 1 – stepped switching is annoying

Surveyor Diagnosed Failure Modes

(64 spaces with zero savings)

- Consciously disabled (55%)
  - 17 – Setpoint adjusted to make system inoperative
  - 7 – Whole system disabled
  - 7 – Sensor taped over
  - 4 – Wire disconnected
- Other reasons for failure (23%)
  - 5 – Installed, but has never worked
  - 4 – Not yet enabled by site staff
  - 3 – Blinds closed, room too dark for photocontrols
  - 3 – Miscellaneous
- Unknown (22%)
  - 14 – Reason for failure unknown

Characteristics of Failed Spaces

The spaces with no savings disproportionately had more of these features:

- Smaller spaces
- Multiple control circuits
- Switching control
- No training of site staff
- Unilateral windows
- Multiple decision makers
- Larger buildings
- Partitions
- Offices
- Direct lighting
- Not classrooms
- Non-north windows

Partitions block daylight

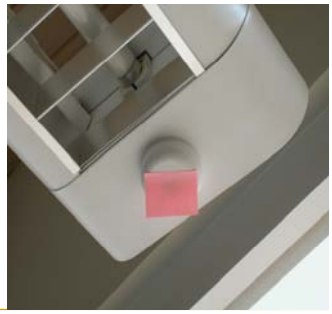
Spaces with partitions were less likely to be functional

Bi-lateral Daylighting Improves Savings

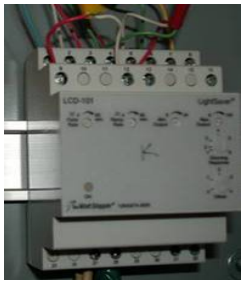
Daylight well balanced, often used in single-loaded classrooms

Taped-over sensor

7 spaces had failed because of taped-over sensors



Operator Adjustments to Controls



Analysis of Spaces with Savings

Six different outcome variables:

- Realized Savings Ratio

$$\frac{Savings\ compared\ with\ uncontrolled\ circuit}{Savings\ predicted\ by\ DOE2}$$

- Full load hours per day savings
- EUI per square foot (kWh/sf•year)
  - EUI per linear foot (kWh/sf•year)
- Peak period EUI per square foot
  - Peak period EUI per linear foot

Analysis of Spaces with Savings

	All spaces in sample	Functioning spaces	High functioning	SBD Whole Building
Energy Savings kWh/sf•year	0.35 @25% 0.09	0.74 @25% 0.19	1.1 @25% 0.28	4.7
Demand Savings W/sf	0.2 @25% 0.05	0.4 @25% 0.1	0.6 @25% 0.15	1.3

- Compare to toplighting average energy savings of 1.2 kWh/sf•year
- Toplighting possible in approximately 50% of comm. floor area
- Sidelighting possible in approx 25% of comm. floor area

Characteristics Associated with Higher Energy Savings:

All p<0.1, i.e., >90% chance it's real

- Older systems
- Photosensor close to window
- Greater effective window aperture
- Site host did not have records of settings or commissioning
- No blinds or curtains in space
- Smaller buildings (<15,000 sf)
- Low ratio of controlled zone depth to window head height
- No clerestories
- Switching instead of dimming
- Sensors NOT looking down
- Spaces other than offices and classrooms
- Greater window area to controlled zone area
- High ratio of window area to controlled zone area
- Remote management instead of local management
- Low ratio of controlled zone depth to window head height to

Dimming vs Switching

- Dimming less likely to fail, but ….
  - Dimming lower RSR, FLH, EUI, Demand savings
  - Dimming less obtrusive – possible for system to work marginally and no one notice
- Switching more noticeable if not working thus people respond
  - Switching "Fix it or break it!"

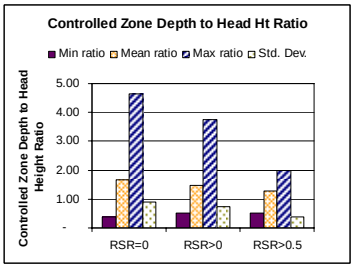
Daylight Quality

Daylight quality was measured in four different ways, three of which had a significant effect on energy savings

Metric	Explanation	Effect on functionality
Horizontal diversity	Ratio of the maximum to the minimum horizontal illuminance measurement	negative, p<0.02
Drop-off Rate	A logarithmic approximation to the reduction in horizontal illuminance from the front to the back of the room	negative, p<0.001
Horizontal variation	The standard deviation of the horiz. illuminances, divided by their mean	negative, p<0.002
Vertical diversity	Ratio of the maximum to the minimum vertical illuminance measurements	not significant

Ratio of Controlled Zone Depth to Window Head Height

- Controlled zone depth should not exceed twice the window head height



Libraries

- Higher FLH, EUI and Demand savings
- Single decision makers
- Large zones
- Large design budgets

Classrooms

- More likely to have some energy savings
  - Single decision maker
  - Public ownership
- Lower FLH savings
  - Shorter hours

Effective Window Aperture

- Spaces with higher effective aperture have higher FLH, EUI, Demand savings
- Definition:

$$\frac{\text{Window area} \times T_{vis\ Glass} \times T_{vis\ Blinds}}{\text{Controlled Lighting Area}}$$

- Similar results for *ratio* of window area to controlled area

Building Commissioning

- Lower FLH and EUI associated with positive response to this question:

  "Do any records exist of any commissioning process or settings?"
  - Could be commissioning of other systems
  - Could be manuals left by electrician
- No time to look for records
- Result not definitive

Age of controls

- Higher FLH, EUI and Demand savings associated with older controls
- If people still recognize the controls are there, likely still working
- Broken or disabled controls forgotten about
- One control from 1989!
- No reports of equipment "failing by itself"
- Equipment life appears to be long

Design Guidance – "Do's"

- Choose the right space
  - Supportive, informed and capable maintenance staff
  - Avoid spaces that don't have much daylight, or have partitions
- Design stage
  - Maximize daylight and electric light uniformity
  - Make sure photocell can see a lot of daylight
  - Use shallow controls zones
  - Specify controls that allow easy adjustment of light levels and settings
  - Divide into smaller zones to avoid "ownership" problems
- Ensure controls are installed properly
  - Manufacturer must provide commissioning instructions
  - Installation and maintenance by manufacturer is desirable
  - "Commission" to check that contractor has actually installed them…
- Train occupants and provide documentation
  - They need to understand the idea, even if they can't observe the function

Design Guidance: "Don'ts"

- Control zone too large
  - Luminaires controlled too far away from windows
  - High partitions
- Control zones too small
  - Not economic to maintain hundreds of controls
- Inadequate equipment
  - Switching controls w/o deadband
  - Dimming controls w/o proportional control algorithm
- Poor sensor placement or masking
  - Looking into fixtures
  - Too far way from windows
- Not installed correctly in the first place
  - Wires not connected
  - Never commissioned (and/or no one knows how to…)
  - Controlling wrong circuit (!)
- Occupants and facilities staff left "in the dark"
  - Not aware of controls and how to adjust, no documentation

Lessons for Commissioning Providers

- Photocontrol systems are a major Cx opportunity
  - Well-designed and commissioned systems can accrue savings for many years
  - Half the installed systems were saving no energy, and could be retro-commissioned
- Work with the design team
  - Help them to understand success factors early in the design process
  - Help them to choose which spaces to install controls in
- Follow up
  - Ensure that the system was installed and commissioned
  - Ensure occupants and operators are trained

Next Steps for Photocontrols in Sidelit Spaces

- The Control System Interface Needs Improvement
  - Occupant adjustment of light level
  - Operator adjustment of system settings
- Daylight Quality "Metrics" are Required
  - Energy savings can only be achieved in visually comfortable spaces
  - Spaces with more uniform daylight save more energy
- Specification Language is Required
  - Clear terms and metrics that enable accurate communication between designers, manufacturers, suppliers, installers and operators
- Verification is Required
  - Verify installation
  - Verify performance
- Understand Occupant Use of Blinds and Lighting Controls
  - Both have a significant effect on savings and are poorly understood

More Information

- Photocontrols studies and issues
  - Owen Howlett, HMG
    - (916)-962-7001
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- For a copy of the study Final Report
  - HMG's website
    - www.h-m-g.com
  - Report soon to be posted on
    - Emerging Technologies Coordinating Council
      - http://www.etcc-ca.com/
    - California Utility Codes and Standards Group
      - http://www.calcodescouncil.com