‘Beyond Widgets’ – Xcel Energy-CO/MN
Systems Performance Specification

This document provides the Xcel Energy – LBNL ‘Beyond Widgets’ project selected system summary description for:

- *Enterprise-level, intelligent networked lighting controls, combined with enhanced daylighting controls (using daylight-redirecting window film and deep daylight dimming to take advantage of interactive HVAC effects).*

This document includes the system features, technology packages, site requirements, and likely energy savings impacts. It will be used as the basis for developing detailed technology specifications, savings metrics and M&V approaches and FLEXLAB testing plans.

The target market is large and small commercial offices undergoing new tenant improvements or gut rehab/major renovation including lighting system replacement.

1. System Features

The following are features of the proposed systems energy-efficiency program package. A technology package options suite will be developed from these features, which will be pursued for testing, validation and program implementation guidance development.

Key aspects for systems selection are their level of functionality (individual autonomous control; enterprise-level, zone control; enterprise-level, intelligent granular control) and their integration with other building systems through additional sensor types tied to the lighting control system. This systems approach requires a different perspective on assessment and validation depending upon levels of functionality; with an emphasis less on installed product and more on performance/outcome, e.g., kWh/sf/year. Projects will include a HVAC energy savings assessment from lighting efficiency improvements as well.

Functional performance requirement

The functional performance requirement is to maintain stable thermal conditions within building HVAC zones, which may be defined according to location (perimeter/core) or type (open office/private office).

Primary control shall be to setpoint temperature during occupied hours and to setup/setback temperatures during unoccupied hours. Secondary control may account for variation in thermal comfort preferences relative to the prevailing outdoor weather conditions (setup/setback) and occupancy (where appropriate/desired).

Control points/variables shall be one or a combination of the following:

- Thermal setpoint
- Airflow rate
- Supply air temperature
- Economizer utilization/mixed air temperature
- Predicted/actual thermal load
- Occupancy sensor signals

- CO_2 sensor signals

HVAC zones shall be consistent with those defined for the lighting system. All control inputs shall be implemented according to system configuration, and each site's specific characteristics and requirements.

Example operational modes:

1. Thermal setpoint
2. Calculated solar gain based on shading position (optimized for daylighting)
3. Maintenance override
4. Occupancy/vacancy

Automated lighting controls for daylighting and occupancy sensing

The lighting control system, of which daylight dimming is a part, may comprise some or all of the following equipment:

1. Digitally addressable ballasts or LED drivers
2. Panel and remote mounted load control relays and dimmers
3. Power supplies
4. Routers, controllers, processors and servers
5. Analog and digital input and output modules
6. Group/scene and manual zone controls
7. Occupant/vacancy sensors and controllers
8. Daylight responsive sensors and controllers
9. Integral time clock control
10. Emergency lighting control
11. Utility "demand response" control.

Functional performance requirement

Daylight photo sensors shall monitor light levels and enable dimming of electric lighting up or down in response to changes in available natural light as required by user type.

Photosensors and controls shall be programmed to ensure minimal lamp cycling (and associated reduced lamp-life and occupant distraction) due to varying daylight levels and should be capable of easy recalibration to accommodate changes in environment/preferences. They should be calibrated to ensure that IES guidelines or code standards are maintained. Occupant sensors may control lighting at the zone or individual workstation level. Lighting output should be adjusted to user requirements (lamp output tuning relative to maximum rated output).

Control points/variables shall be one or a combination of the following:

- Occupancy
- Workplane illuminance (measured directly or calculated from measured reflectance)

Example operational modes:

1. Scheduled

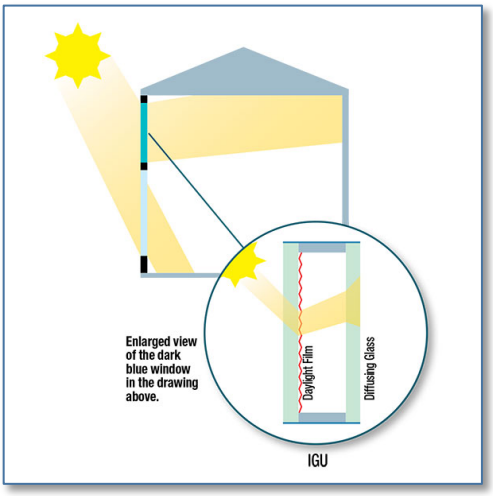
2. Occupied/vacant
3. Daylight dimming

Notes on Integration of Systems

Operation of automated lighting controls shall take also into account energy optimized performance of daylighting dimming controls to ensure minimal glare issues arise than necessary.

Occupancy control shall be at the individual cubicle or private office level in order that control signals may appropriately control the local lighting levels or HVAC operation according to a) verified energy performance and/or b) occupant preferences.

Daylight-redirecting window film for extended daylighting



The building glazing system may comprise some or all of the following components:

1. Daylight redirecting film (applied to interior glass surfaces) that brings natural light deeper into the building's interior by changing the light's direction as it passes through windows. The film redirects light toward the ceiling, reducing the need for artificial light throughout the day.

2. Technology Packages

The intent is to allow a range of different component technology options that meet the system features described above. The program incentives would be paid based on overall integrated, system performance rather than component performance or features. The technical requirements for each component are summarized below, followed by technology packages that will be selected for testing.

In order to evaluate the savings, specific technology packages need to be specified and tested. It is infeasible to test all possible technology packages, as there are too many permutations and component combinations. Therefore, the project team will be testing three technology packages that approximate the range of savings and likely program offerings for this measure.

- **Package 1:** represents a basic package integrating zone-level daylighting and lighting controls, with zonal HVAC controls.
- **Package 2:** represents an enhanced package with daylight-redirecting window film, integrated networked, zone-level lighting controls, luminaires with integral occupancy and photosensors, and HVAC controls.
- **Package 3:** represents the fully integrated package with daylight-redirecting window film, integrated networked, highly granular lighting controls, a dense sensor configuration (workstation-specific luminaires with integral occupancy and photosensors) and HVAC controls.

3. Candidate Site Requirements

The likely minimum site requirements for the system are:

- 10 ft floor-to-ceiling heights with dropped ceiling/plenum for routing of power and communications.
- Air-based delivery systems with hydronic supply.
- BACNet or similar architecture to support inter-communications
- HVAC operation based on thermal setpoint control strategy consistent with ASHRAE 90.1
- BMS with trend facility (or alternative i.e., for rooftop units (RTUs))

Additional requirements for preferred sites:

- Moderate to large windows (window-wall ratio > 40%).
- Clear or low tint glazing (double/triple).
- 2nd or 3rd generation linear fluorescent lamps and ballasts with zonal control or scheduling.
- Minimum of 8 hours daily average occupied hours.
- Perimeter constitutes significant proportion of total floor area (~>25%)
- Open office partitions 4 ft. or less.
- Better to have open office on perimeter than closed office.

4. Energy Saving Impacts

Baseline Case

For Colorado, the minimum compliant building with the absence of energy modeling compared to ASHRAE 90.1-2010 code as modified or local code when more stringent. The EDA Modeling Protocol is based on a utility modified version of the ANSI/ASHRAE/IESNA Standard 90.1-2010 Energy Standard for Buildings Except Low-Rise Residential Buildings utilizing Appendix G.

For Minnesota, code is based on the 2012 International Energy Conservation Code® and ANSI/ASHRAE/IES Standard 90.1-2010: Energy Standard for Buildings Except Low-Rise Residential Buildings. All prescriptive measures utilize the energy savings calculations listed in the State of Minnesota Technical Reference Manual For Energy Conservation Improvement Programs, Version 1.2, Effective: January 1, 2015 – December 31, 2015, which specifies the following baselines:

- New construction: building code or federal standards.
- Retrofit: existing equipment or the existing condition of the building or equipment

Baseline Building Selection:

- The building selected for this study is based on an office building with a typical 2'x4' acoustical grid ceiling.
- Floor Area: 25,000 sqft (typical per story)
- Ceiling Height: 9'-0"
- Windows:
    - Sill Height: 2'-6"
    - Top of Window: 8'-0"
    - Glazing/Façade Area Ratio: 40%
    - Glazing Type: Double Low-e Tvis = 0.65
    - 40% window-to-wall ratio
    - Manually operated interior shading

For the purposes of this project, the baseline for comparing the technology packages will comprise of the following:

- Lighting and Control System Design
    - Existing Luminaire: 2'x4', 3-lamp T8, recessed parabolic troffer with scheduled control
    - Existing Layout: 8' x 8'
    - Resulting Task-plane Illuminance: 55 footcandles average
    - Target Task-plane Illuminance: 35 footcandles average
    - ASHRAE minimum control zone: 2,500 sqft.

Interior Space Planning

Two different floor plan strategies for space planning (see figure below) could be considered to compare the energy effects of:

1. A **traditional space plan** with perimeter private offices located near the windows and interior open offices.
2. An **inverted space plan** that maximizes daylight availability by having perimeter open offices located near the windows, and interior private offices.

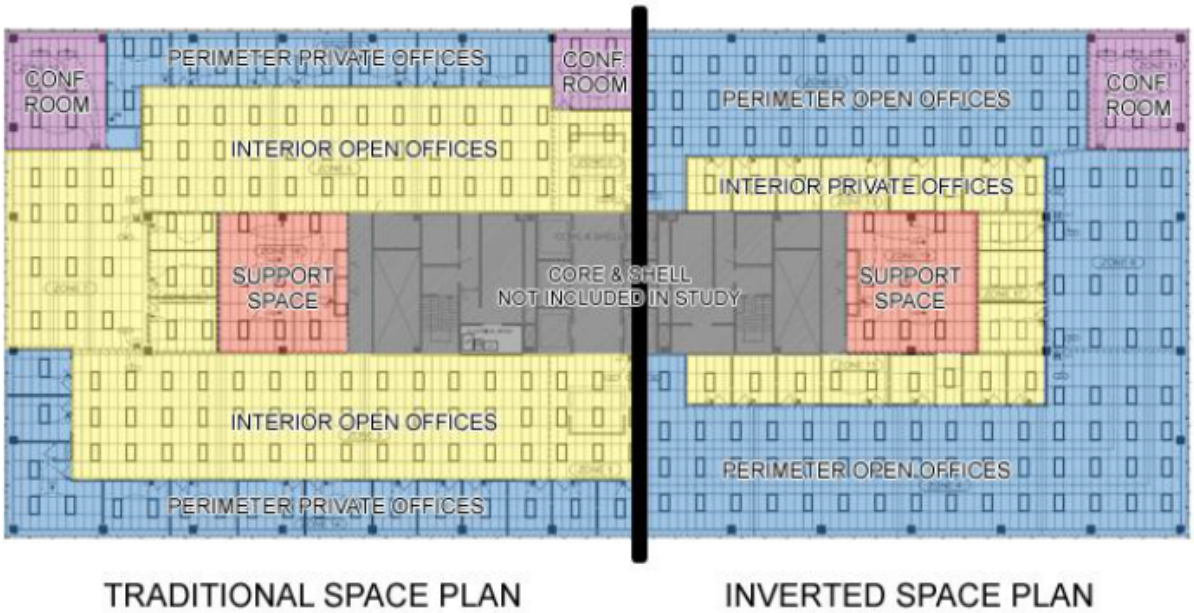


Figure 1: Space Planning Diagram (Clanton Assoc.)

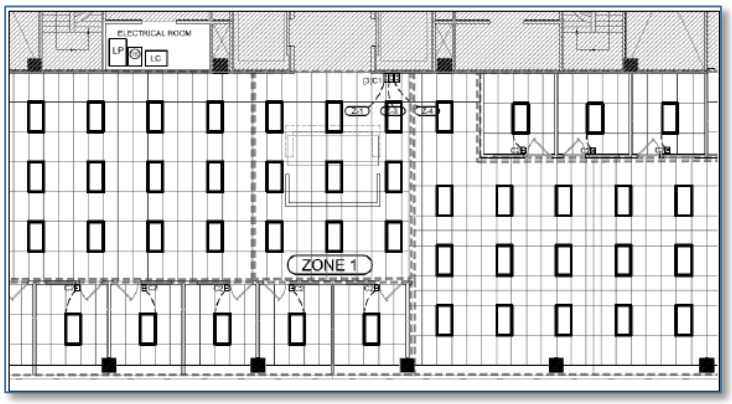


Figure 2: Typical Recessed 2'x4' Fluorescent Luminaire Layout (8'x8') (Clanton Assoc.)

- HVAC and Control System Design
  - VAV HVAC system with scheduled thermostatic setup/setback control.

Proposed Technology Package Savings

Daylight-based dimming is a proven but underutilized energy-efficiency technology, particularly within the context of utility programs which mostly cater to prescriptive component-based efficiency measures. An LBNL study (Williams et al. 2012) showed that for offices, daylighting alone yielded an average lighting energy savings of 41% (N=78 projects), institutional tuning yielded 38% average savings (n=17), personal tuning, 34 % average savings (n=18), and occupancy provided 30% average savings (n=66) (Figure 3: Average Energy Savings (%) By Control Strategy (Williams, et al. 2012)).

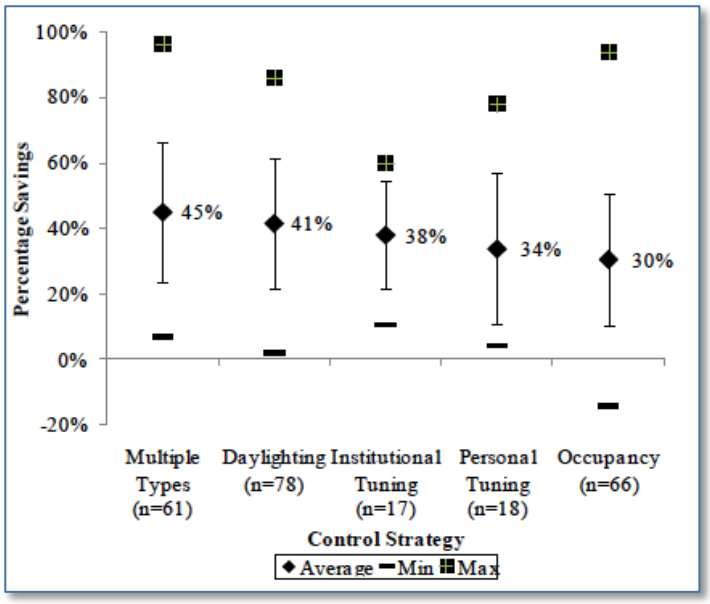


Figure 3: Average Energy Savings (%) By Control Strategy (Williams, et al. 2012)

Adding enhanced daylighting with light-redirecting window film extends the effective daylighting zone and therefore, the potential energy savings associated with daylight dimming and HVAC controls, a better visual environment, and higher savings realization. For example, post-occupancy LBNL study of the New York Times headquarters building (Lee et al. 2013) showed 38% lighting energy savings compared to code, with a simple payback of 4.1 years (Figure 4: Lighting energy use savings in the New York Times headquarters building (Lee, et al. 2013)). Improved daylighting practices employing automated shades, in this case, caused daylight to be well managed irrespective of differences in daylight availability – for lower floors with greater urban obstructions, the shades were automatically raised more often and for upper floors with less urban obstructions, the shades were lowered more often to control sun and glare. These and other non-energy benefits (e.g. lower cost for reconfiguring lighting system compared to hardwired systems) serve as an added incentive to increase adoption.

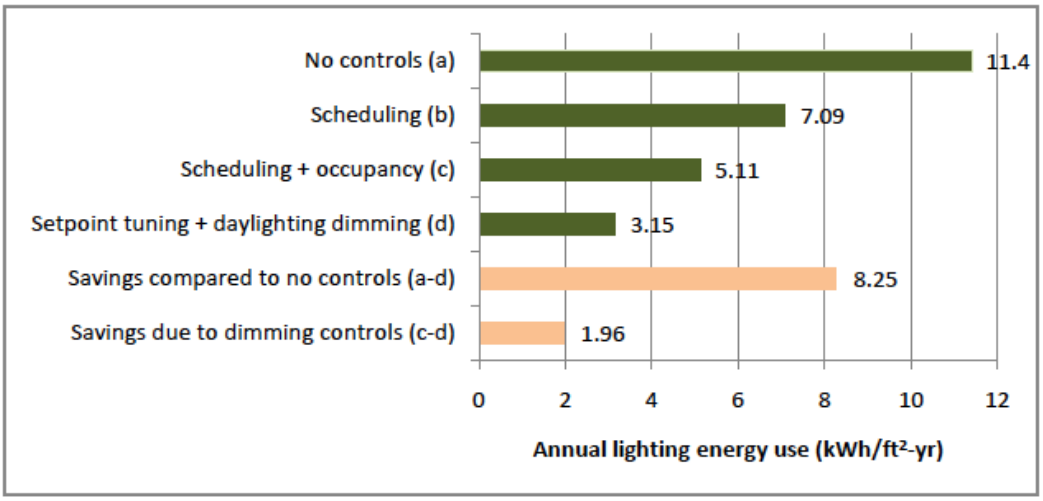


Figure 4: Lighting energy use savings in the New York Times headquarters building (Lee, et al. 2013)

Employ a systems level approach to lighting incorporating greater control granularity, dense sensor networks (wired or wireless), and fewer luminaires (optimally task-oriented, i.e., workstation-specific fixtures) that enables much greater energy savings and enhanced functionality.

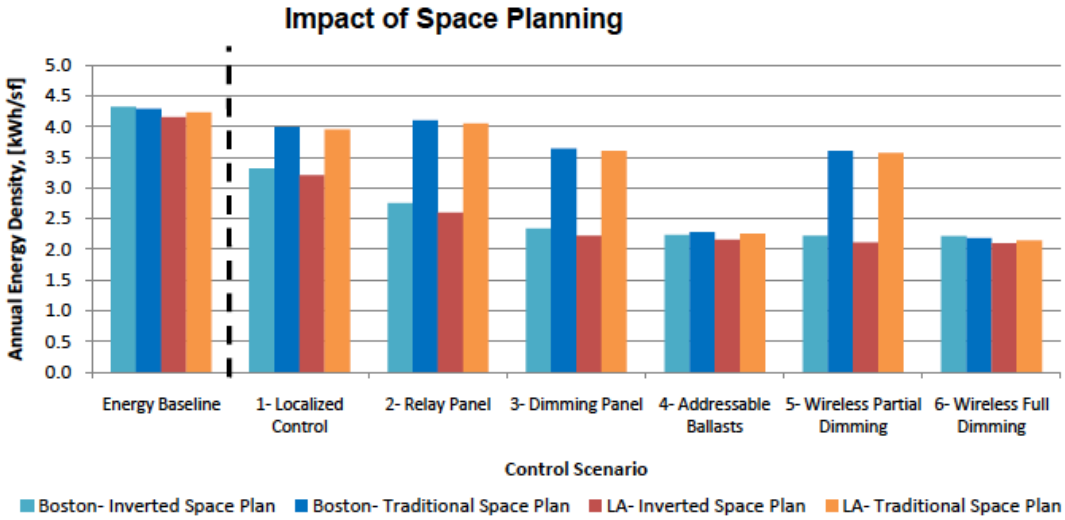


Figure 5: Annual Energy Density, Split by Location & Space Planning (Clanton Assoc.)

Notes on Systems Measurement and Verification (M&V)

LBNL intends to employ a graduated approach to M&V with respective accuracy and savings metrics.

Purpose of metrics: M&V

- Lighting kWh during on-hours.

- Zonal cooling kWh during on-hours (scheduled occupancy hours). Calculated from VAV airflow, system pressure and SAT. Central plant and air handler effects are highly dependent on rest of building and therefore, difficult to measure specific zonal impacts. (Fan energy may be an exception)
- Zonal heating kBtu during on-hours. Calculated from reheat and/or perimeter heating flow/temps. Does not capture savings at central plant. (Pumping energy ~ 2-way or 3-way valves)
- Chiller plant kWh – consider using average kW/ton.
- Boiler kBtu – consider average % efficiency.
- kWh/sf/yr for relevant zones.
- kWh/sf/yr for whole bldg.

Performance metrics

- Workplane illuminance
- Spectral distribution-CCT
- Air temp
- Glare index

References

Lee, E.S., L.L. Fernandes, B. Coffey, A. McNeil, R. Clear, T. Webster, F. Bauman, D. Dickerhoff, D. Heinzerling, T. Hoyt. 2013. A Post-Occupancy Monitored Evaluation of the Dimmable Lighting, Automated Shading, and Underfloor Air Distribution System in The New York Times Building. LBNL-6023E

Williams, A., B. Atkinson, K. Garbesi, F. Rubinstein, Lawrence Berkeley National Laboratory. Page, E, Erik Page & Associates, Inc. May 2012. Quantifying National Energy Savings Potential of Lighting Controls in Commercial Buildings. LBNL-5895E

Williams, A., B. Atkinson, K. Garbesi, F. Rubinstein. 2011. A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings. Technical report. LBNL-5095E.

U.S. Department of Defense DOE ESTCP, 12/01/2013. Cost and Performance Report: Daylight Redirecting Window Film, Environmental Security Technology Certification Program

Anothai Thanachareonkit, 10/26/2013. Empirical Assessment of a Prismatic Daylight-Redirecting Window Film in a Full-Scale Office Testbed, Buildings Technologies Group, LBNL, IESNA 2013 Annual Conference

Wireless Lighting Control, A Life Cycle Cost Evaluation of Multiple Lighting Control Strategies, Prepared For: Daintree Networks; Clanton & Associates, Inc., Dane Sanders, PE, LEED™ AP, Darcie Chinnis, EI, LEED™ AP,