# LBNL-ComEd 'Beyond Widgets' Project
# Automated Shading Integrated with Lighting and HVAC Controls
# Customer Technical Specification

**DRAFT 9-1-16**

## 1 System Features

ComEd considered a list of several systems and selected automated shading integrated with lightng and HVAC controls. The key features of this system are:

Automated Shading: The automated interior shading element will be roller shades. The functional requirement is for the shades to control solar gain through perimeter windows so that envelope-related thermal loads are minimized while meeting daylighting requirements. In unoccupied perimeter areas, the shades will be deployed according to the prevailing HVAC mode of operation (deployed in cooling mode, retracted in heating mode).

Lighting Controls: The lighting control is in response to occupancy and illuminance levels. Occupancy-driven control will switch lights on/off or dim to minimum background levels. Illuminance-driven control will dim lights continuously based on daylight availability.

HVAC Controls: The primary HVAC control is in response to thermostatic setpoints, with scheduled setup and setback for unoccupied periods. Additionally, occupancy sensors used for the shading/lighting system may be used for setup/setback in response to vacancy during occupied periods, as well as reducing ventilation air.

## 2 Energy Impacts

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 meta analysis study (Williams et al. 2011) showed that daylighting alone yielded an average lighting energy savings of 27% (N=18 projects) for offices and 29% (N=7 projects) for education (Table 2).

*Table 1.Energy savings from LBNL meta-analysis of lighting controls studies (Williams et al. 2011)*

| Building Type (Alone) | Occupancy | Daylighting | Personal Tuning | Institutional Tuning | Multiple Types |
|---|---|---|---|---|---|
| **Office** | 22% (n=23) | 27% (n=18) | 35% (n=13) | 36% (n=11) | 40% (n=24) |
| **Warehouse** | 31% (n=4) | 28% (n=1) | - | - | - |
| **Lodging** | 45% (n=2) | - | - | - | - |
| **Education** | 18% (n=5) | 29% (n=7) | 6% (n=2) | - | 34% (n=7) |
| **Retail (other than Mall)** | - | 29% (n=3) | - | 60% (n=1) | - |
| **Healthcare Inpatient** | - | - | - | - | 35% (n=1) |
| **Public Assembly** | 36% (n=2) | 36% (n=1) | - | - | - |
| **Healthcare Outpatient** | 23% (n=1) | - | - | - | - |
| **Other** | 7% (n=1) | 18% (n=1) | - | - | - |

Integrating automated shading with daylight dimming and HVAC controls has the potential to yield higher savings, 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 1). The automated shades 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.

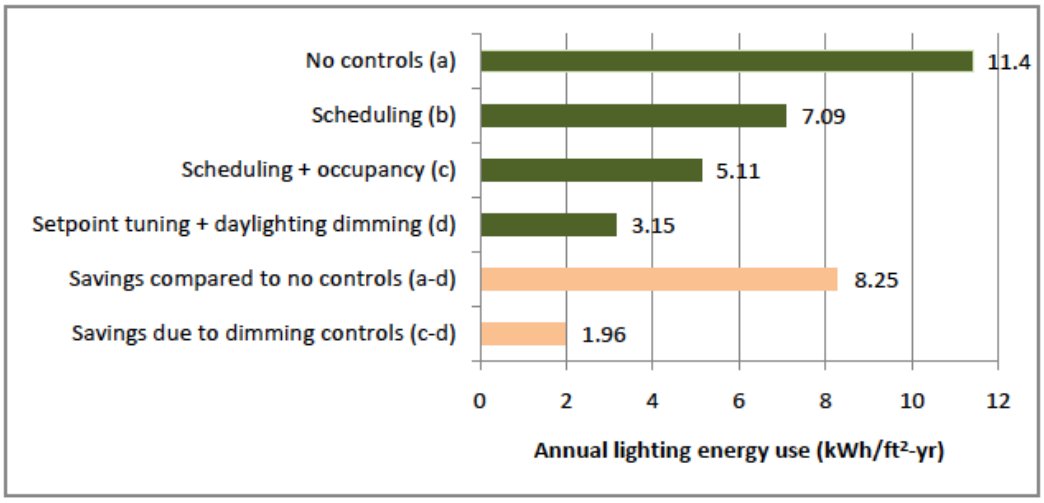


*Figure 1. Lighting energy use savings in the New York Times headquarters building (Lee et al. 2013)*

# 3 System Specification

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 system performance rather than component performance or features. The technical requirements for each component are summarized below.

### *3.1.1 Automated Shading*

An automated interior shading and shade control system should comprise the following elements:

- Shading element – roller shades (various fabric options) or venetian blinds.
- Motor for shades/blinds operation, and housing for blinds when retracted.
- Keypads to enable user control and override of automatic operation.
- Routers, controllers, processors and servers.
- Control system that utilizes an automated, computer server-based control system with the ability to receive inputs from multiple occupancy sensors and photo sensors.
- Sensors for control inputs
- Programming software

The primary control objective is to control glare while maximizing daylight availability. Setpoints for glare control and maximizing daylight should be set based on use characteristics and user preferences. Additionally, occupants should always have manual override capability. Primary control shall be in response to solar conditions, based on real-time solar radiation sensor input. In addition, a combination of one or more of the following inputs may be used:

- Sun position
- Direct solar radiation
- Diffuse solar radiation
- Façade azimuth
- Interior and/or exterior surface luminance
- Interior and/or exterior illuminance

Additional secondary control may include a combination of vacancy and HVAC mode, as follows:

- When the zone is vacant and HVAC is in cooling mode, shades are fully deployed.
- When the zone is vacant and HVAC is in heating mode, shades are fully retracted.

Additional specific requirements:

- Roller shades should have an openness factor between 1-3%. The exterior reflectance should be greater than 60%. Interior reflectance should be lower than exterior reflectance.
- The control system should allow for at least 3 shade height settings for roller shade (including fully raised and fully lowered), and at least 3 height settings (similarly as for roller shades) and 2 slat positions (fully open and closed) for venetian blinds.
- The types, locations and number of sensors shall be determined by the Shade Controls System Supplier.
- The shades shall block direct sun so that the depth of direct sun penetration is no greater than a specified horizontal depth from the face of the window wall at floor level. The specified maximum penetration distance may vary for different perimeter

areas based on user requirements. The deployment of shades should consider blocking of the sun by external obstructions such as surrounding buildings.

- Response to variable luminance should be limited so as to avoid shade movement hysteresis. Response to variable sky conditions should be immediate when going from cloudy to sunny, and delayed when going from sunny to cloudy.
- The shades shall control glare so that the average window luminance viewed from any angle within the work space is no greater than a specified level (e.g. 2000 cd/m2) during the day. This includes all periods throughout the day whether there is or is not direct sun in the plane of the window.
- The control system should have the capability to interface with HVAC control system or BMS.
- The shade control database should maintain archived log files of key parameters such as position of shades, glare photo sensor data, profile angles, radiometer readings and system control mode.

All control inputs shall be configured to reflect each site's specific characteristics and requirements.

### 3.2 Automated lighting controls

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

- Digitally addressable ballasts or LED drivers; ballast and lamp combinations compatible with dimming controls.
- Panel and remote mounted load control relays and dimmers
- Power supplies
- Routers, controllers, processors and servers
- Analog and digital input and output modules
- Group/scene and manual zone controls
- Occupancy/vacancy sensors
- Photosensors
- Integral time clock control
- Emergency lighting control
- Utility "demand response" control.

The functional performance requirement is that 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. Additionally, lights shall be turned off or dimmed to minimum levels in unoccupied zones.

Additional specific requirements:

- Daylighting sensors and controls shall be programmed to ensure minimal lamp cycling (and associated reduced lamp life and occupant distraction) and should be capable of easy recalibration to accommodate changes in environment/preferences. They should be calibrated to ensure that IES guidelines[1] are maintained. The control system should be capable of controlling multiple zones using the input from a single sensor, allowing separate adjustable settings for each control zone. The system should allow for

[1] For example, for commercial offices, 30 footcandles on the workplane.

variable target setpoints. The location and number of the photo sensors should be optimized by the control system supplier.

- Occupant sensors may control lighting at the zone or individual worker level. Lighting output should be adjusted to the requirements of the user (tuning of lamp output relative to maximum rated output). Occupancy sensors should be dual-technology. Sensors should allow remote control adjustments of operational parameters (sensitivity, time delay).
- Group/scene controllers shall be compatible with other components of the lighting control system. Devices shall contain on/off group, preset scene functions, or dim up/dim down interface through front panel. Programming of new scenes or zone assignments must be easily accomplished by authorized personnel from the space being controlled.
- Daylighting sensors should not be in the same housing or location with occupancy and vacancy sensors if proper location for one compromises the successful operation of the other.
- The lighting control system should provide remote monitoring and reporting. It should provide report and trends on the following: energy usage, target setpoint map, switching events, lamp hours, commands usage, system failures.
- Database management system that logs all commands from the LCS. The log file should provide deterministic values including, but not limited to: photosensor data, occupancy sensor state and system control mode (auto, manual and maintenance).
- Lighting system energy use should be measured at the panel level for each zone(?).
- Self-diagnostic and self-corrective features.

All control inputs shall be configured to reflect each site's specific characteristics and requirements.

### *3.2.1 HVAC Controls*

Integrated HVAC controls/equipment shall include one or more of the following:

- BACnet control communications
- Variable frequency drives on fan and pump motors
- Modulating valves on heating/cooling loops
- Outdoor air temperature reset
- Networked mechanical equipment controllers

Optional control input:

- Occupancy sensors at the sub-zone (i.e individual private office/cubicle) level

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

For integrated shading, lighting and HVAC control, HVAC zones shall be consistent with those defined for the lighting system. All control inputs shall be implemented according to system configuration, and each sites specific characteristics and requirements.

## 4 Candidate Site Requirements

Utility customer site requirements to apply for the incentive program are likely to include the following.

At a minimum:

- 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 capability.

Additional requirements for preferred sites:

- Moderate to large windows (window-wall ratio >30%).
- Clear or low tint glazing (double/triple).
- Digitally addressable dimming ballasts or LED drivers.
- Minimum of 8 hours average daily occupied hours.
- Perimeter areas constitute significant proportion of total floor area (>25%)
- Open office partitions 4 ft. or less.
- Preferable to have open office on perimeter rather than closed office.

## 5 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

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