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Beyond Widgets: Validated Systems Energy Savings and Utility Custom Incentive Program Systems Trends

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Abstract

Energy efficiency upgrades to buildings to date through avenues such as utility incentive programs have been largely limited to component-based products (e.g., lamps, RTUs). While some utilities do provide 'custom' incentive programs with whole building and system level technical assistance, these programs require deeper levels of analysis, resulting in higher program costs. This results in custom programs being restricted to utilities with greater resources, and are typically applied mainly to large or energy-intensive facilities, leaving much of the market without cost effective access and incentives for these solutions. In addition, with increasingly stringent energy codes, cost effective component-based solutions that achieve significant savings are dwindling.

Integrated building systems (e.g., integrated façade, HVAC and/or lighting solutions) can deliver higher savings (Regnier et al. 2017) that translate into large sector-wide savings if deployed at the scale of these programs. However, systems application poses a number of challenges – energy savings assessments are inherently more complex and are not easily suited to the deemed measure model, and implementation of systems can be more disruptive.

This paper presents the outcomes of a project to develop validated utility incentive program packages for three specific integrated building systems, in collaboration with ComEd, a consortium of California Public Owned Utilities (CA POUs) (Northern California Power Agency(NCPA) and the Southern California Public Power Authority(SCPPA)), and Xcel Energy (CO, MN). Previous work described the potential for energy savings of these systems at the individual and market level, early test findings for the task-ambient lighting system, and described the work products to develop utility incentive programs (Regnier et al. 2016). This paper presents validated end use energy savings of all three systems showing energy savings of ~20% for automated shading combined with daylight dimming (does not include light fixture retrofit savings); 30-46% for task-ambient lighting systems combined with plug load occupancy controls, depending on technology package and office building size (no daylight dimming impacts); and ~94% in the south-façade daylit zone for workstation specific lighting systems with daylight dimming (including lighting retrofit and task tuning). Using a U.S. Department of Energy (DOE) reference building model (DOE 2018), this translates to whole building savings of 2-5% (large-medium commercial), 12-23% (large-small commercial), and 13-15% (medium-large commercial) for these systems respectively. Early findings from the utilities in deploying these systems through their incentive programs indicate that deployment methods such as direct install programs might be best suited for these integrated systems.

Further, early findings from a scoping study across custom utility programs and federal retrofit programs indicate that component level retrofits are still prevalent even in these programs, pointing towards an opportunity for deeper energy savings deployment. High performance retrofit case studies demonstrate that deeper energy savings is possible through

integrated approaches. Market stakeholder interviews indicate however that there is generally a low level of awareness of the potential for energy savings of these three integrated systems.

Introduction

A recent study (Regnier et al. 2017), indicated that 30%+ whole buildings savings were achievable through a component based retrofit approach throughout the building, but up to 80%+ savings were possible for a highly integrated whole building systems retrofit. The opportunity for increased energy savings through adoption of integrated buildings systems is clear. However, deployment of integrated building systems solutions can be comparatively complex and disruptive to implement, often requiring whole building analysis, resulting in highly customized solutions and approaches to implementation. Systems strategies for energy efficiency include efficient end use systems, where equipment, distribution and controls methods are designed and operate at higher overall efficiencies, and integrated systems that incorporate design and/or controls strategies that coordinate for energy savings across multiple end use systems.

Previous work (Regnier et al. 2016) documented the market opportunity, and need, for achieving deeper levels of energy savings possible through the adoption of energy efficient integrated building systems. This work also recognized the unique deployment potential represented by utility incentive programs in gaining further market adoption of systems based energy savings, but pointed to incentive program structures that currently favor 'widget' based upgrades (e.g. RTU or light replacement), such as through deemed savings programs.

The current work describes the completion of a 3 year project funded by the U.S. Department of Energy (DOE) to work with sets of utilities to develop systems level incentive programs. The objective of this effort was to provide utilities and their customers with a streamlined package of information, tools, and validated savings data necessary to implement system-level projects, achieving deep energy savings, without the complexity and cost associated with custom programs. The specification of each system package is described in the previous work. Validated energy savings from testing of each of the three integrated systems is presented here. Complete program manuals with all package elements, including a complete description of the FLEXLAB® test conditions is available online (cbs.lbl.gov/beyond-widgets-for-utilities).

Utility custom programs remain an important energy efficiency deployment strategy, however a technology review of these programs has not been identified to date by the authors. In an effort to inform future work in the streamlined deployment of building system technologies, DOE has funded a scoping study to identify system technology adoption trends through current custom programs. At the time of writing, project level data was just starting to be collected, however early findings are presented.

Packaged Integrated Systems: Validated Energy Savings

Three integrated systems were identified in collaboration with their respective utility partner(s) for development into a packaged streamlined incentive program. A series of tests were designed to be conducted in FLEXLAB (flexlab.lbl.gov). FLEXLAB is a controlled, highly instrumented building technologies test facility that offers unparalleled granularity in performance measurement to assess the energy savings potential of each system, under a range of conditions expected to occur in the marketplace. Test scenarios include a range of different baseline conditions to represent typical existing conditions or code minimum conditions, which are the baseline for comparison for some utility programs. Building on the work previously reported, all three systems have completed testing and present their validated energy savings. All validated results were used to develop streamlined assessment methodologies, along with quantified uncertainty amounts for use in the utility incentive programs.

Automated shading with daylighting dimming controls (Developed with ComEd)

ComEd considered several systems and selected automated shading integrated with lighting and daylighting controls. HVAC controls integration was considered earlier, but removed from the system for the practical condition that HVAC zones were not likely to match lighting zones and occupancy sensors in much of the target market. ComEd identified two target market segments: offices and schools. For offices, the focus will be on medium and large size buildings. The package targets both retrofit and new construction. The key system features are:

- Automated Shading: automated interior roller shades. The functional requirement for the shades is to control glare while maximizing daylight availability.
- Lighting Controls: the lighting control is in response to occupancy and illuminance levels. Occupancy-driven control switches lights on/off to a tuned level that meets lighting setpoint for workplane illuminance. Illuminance-driven control dims lights continuously based on daylight availability.

Daylight-based dimming is a proven but underutilized energy-efficiency technology, particularly within the context of utility programs. 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. A post-occupancy 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.

LBNL commissioned a market analysis to estimate the savings in the two market segments, based on existing literature for the ComEd market. The total technical potential for these segments is 519-633 GWh of savings. The Total Resource Cost (TRC) criterion was 0.25-0.28 for a retrofit scenario and 0.44-0.53 for a Replace on Burnout (ROB) scenario. Using TRC criteria, this system is cost-effective only for specific sub-segments and only when evaluated using incremental system costs (ROB scenario). This is primarily due to the low avoided cost rates in Illinois, which are about $0.04/kWh. However, from a customer perspective these systems are cost effective with the average rates of about $0.10/kWh.

The key objectives of the FLEXLAB testing were to: 1) analyze lighting and HVAC energy savings from automated shading integrated with lighting, for Chicago climate conditions; 2) evaluate visual comfort parameters; and 3) evaluate level of effort and uncertainty associated with different levels of measurement. The test case (i.e. automated shading integrated with tuned LED lighting) and the baseline case (i.e. manually operated venetian blinds and tuned LED lighting with no daylight-based dimming) were tested at the same time under identical conditions using the two cells of the FLEXLAB rotating testbed. In order to obtain an assessment of HVAC loads in Chicago climate, the internal temperature setpoints were adjusted in real time to match the indoor-outdoor temperature difference in Chicago. Annual TMY solar data were compared for Chicago with the test conditions and found to be equivalent. In extending the test results to annualized savings, exterior global horizontal radiation – a variable available in TMY data - was used as the key variable to determine savings potential. FLEXLAB testing covered 16 configurations of orientation (south and west), daylight zone size (10’, 15’, 25’), window-to-wall-ratio (WWR) (0.3, 0.4), and lighting type (LED, T-8 Fluorescent). Each configuration was tested repeatedly for short periods of several days across the 6 month testing period.

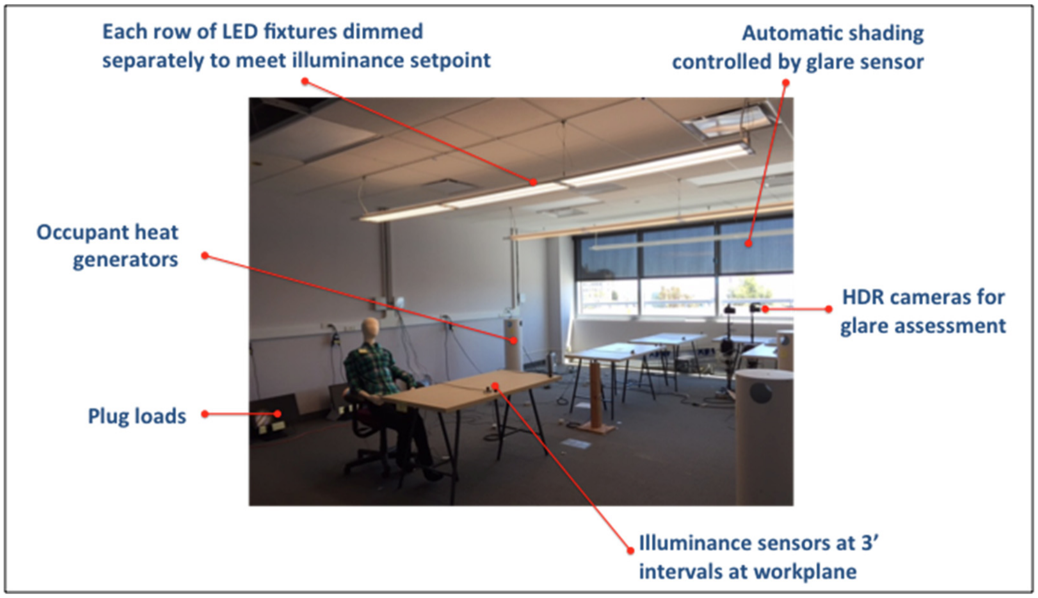

Figure 1. Internal view of FLEXLAB test cell set up for automated shading and daylighting.

Test period savings were extrapolated to annual savings using regression models of the test period data. South orientation shows a mean of 19% annual lighting energy savings, with a range of 12-26% (at 95% confidence). West orientation shows a mean of 24% annual lighting savings, with a range of 19-30% (at 95% confidence). Savings can vary widely over the course of the year, due to change in sun angles and associated deployment of shades (Figure 2). It is important to reiterate that these *savings are exclusively attributable to automated shading and daylight dimming* and will be additional to savings from lighting upgrades. In particular, these savings do not include the savings from tuning or HVAC interactive effects.

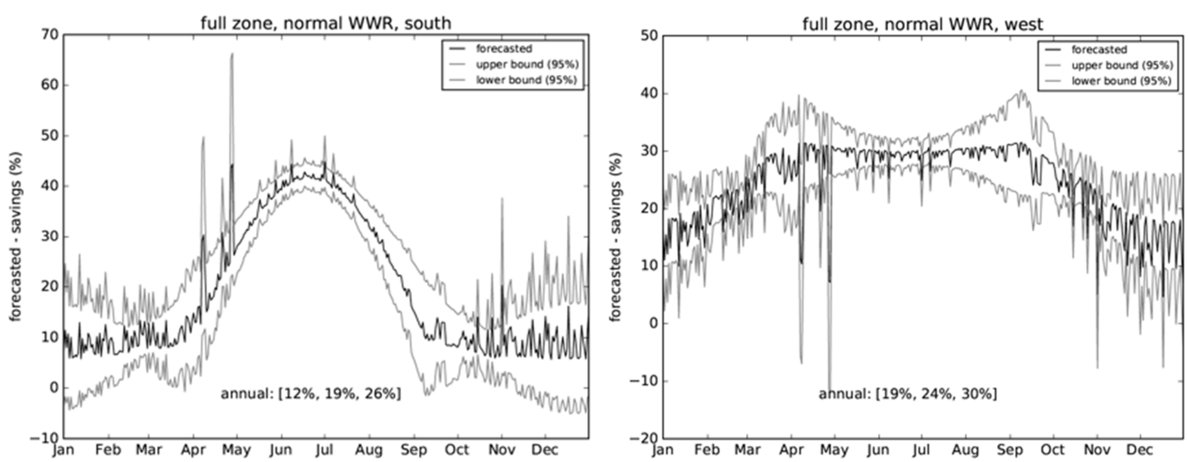

Figure 2. Annual lighting savings for Chicago for south (left) and west (right)

We estimated whole building savings for four building types using the DOE reference building EnergyPlus simulation models (U.S. DOE 2018) in combination with the FLEXLAB lighting savings results, adjusted to account for savings from institutional tuning. The table below shows the whole building savings estimates for the reference buildings. The visual comfort analysis showed that the system maintained workplane illuminance and daylight glare probability at satisfactory levels throughout the test period.

Table 1. Savings for automated shading from lighting dimming and tuning

Reference Building	Retrofit Zone Savings		Whole Building Annual Energy Savings		
	Lighting Annual Energy (%)	Lighting EUI Savings (kWh/sqft/yr)	Lighting Svg %	Total Elec Svg %	Site Energy Svg %
Large Office	36%	1.13	16%	5.0%	2.6%
Medium Office	36%	1.13	22%	4.5%	3.5%
Primary School	30%	1.57	20%	9.0%	4.8%
Secondary School	30%	1.56	14%	6.2%	2.7%

Lighting and plug load occupancy controls with task-ambient lighting retrofit (developed with California Publicly-Owned Utilities (CA POUs))

The CA POU membership selected two discrete packages of advanced lighting and plug load controls, for deployment in commercial offices. The key features of this system are:

Lighting and lighting controls: overhead lighting controlled by occupancy at the zone-level. Occupancy controls switch lights on and off. Output from overhead lighting dimmed to an ambient level somewhat lower than standard practice (200 lux floor-level vs. 300 to 500 lux at the workplane), with any lighting deficit perceived by an occupant to be supplemented by the use of a personal task light. This strategy is generally referred to as a task-ambient approach.

Plug load controls: desktop equipment controlled by occupancy at the cubicle level. Occupancy controls switch power on to controlled power receptacles. All desktop equipment, except for computers, powered via the controlled power outlets to ensure maximum energy savings – including the task light used to supplement workplane light levels.

Two packages are provided, differentiated by the degree of installation effort and their need to meet California's Title 24 Energy Code. The 'basic' package is a 'plug and play' system, requiring no rewiring, and consists of an overhead lighting lamp change-out and installation of software-enabled controlled power outlets over top of existing power receptacles. The 'advanced' package consists of replacement of controls and/or fixtures for overhead lighting, with a plug load control solution that requires rewiring, and meets Title 24 requirements.

The CA POUs identified offices as the target market, with the basic package anticipated as being more attractive to small and medium-sized buildings due to the lower costs and the absence of triggering California's T24 requirements. All packages allow for the occupant to be able to modify task lighting, and have occupancy based controls. This system was tested in FLEXLAB's Lighting and Plug Loads testbed, which consists of a permanently occupied commercial office environment, with power measurement and controls capabilities at the device level. For this system the following test cases were developed, representing the range of existing or baseline conditions, as well as a range of applicable system applications. Table 2 describes the packages and baselines studied.

Table 2. Task/ambient lighting and plug load occupancy controls retrofit and baseline packages

	Test Baseline	Retrofit Package
Package 1	Existing building condition – commercial office	'Plug and play' LED lamp retrofit for task-ambient lighting and wireless plug load control of desktop loads, including task lighting, via receptacle overlay
Package 2	Existing building condition – commercial office	Dimmable LED lighting fixtures replacement / lighting controls retrofit for task-ambient lighting and retrofitted power receptacles with wired or wireless plug load control of desktop loads, including task lighting

A range of test scenarios (Table 3) was then developed to allow for performance data to be collected across the range of possible baseline conditions, and technology packages. A minimum of 2 months was targeted for testing under each condition.

Table 3. Test scenario conditions

Test Description	Baseline	Test Condition
1. Reduced overhead lighting power density (LPD) without controls and plug load controls	Existing building conditions (multiple measured baselines / empirical measured data from field tests)	Linear LED lamp replacement (with integrated driver) in existing fixtures, and schedule and/or occupancy control of plug loads.
2. Existing overhead light fixtures with new controls, and plug load controls.	Existing building conditions (multiple measured baselines / empirical measured data from field tests) and Title 24.	Retrofit of controls to existing lighting system, and schedule / occupancy control of plug loads.
3. Test #2 with LED replacement tubes added	Existing building conditions (multiple measured baselines / empirical measured data from field tests) and Title 24.	Retrofit of LED replacement tubes and controls to existing lighting system, and schedule / occupancy control of plug loads.
4. Overhead fixture replacement, reducing operational LPD, and plug load controls.	Existing building conditions (multiple measured baselines / empirical measured data from field tests) and Title 24.	Retrofit of LED fixtures with comprehensive controls, and schedule / occupancy control of plug loads.

Data was measured at a high granularity – i.e. electricity metered per single light fixture (in this case pairs of 4 foot pendants for existing fixtures or single fixture for LED retrofit fixtures) or per each single duplex power receptacle.

There were measurable energy savings arising from each of the tested technology packages, and these were extrapolated to represent annual energy savings, and are summarized in Table 4 below. Note that although TP2a and TP2b were specified to meet or exceed Title 24 performance requirements, energy savings would be claimed against the existing building condition per the CA POU's evaluation practices. These results were broadly in line with the performance expected, and therefore met the requirements of a prospective rebate program. The two discrete system elements (overhead lighting and plug load control respectively) however, did not perform entirely as anticipated. Energy savings from plug load control were lower than expected, and it is possible that with heavy task light use (i.e. switched on for the entirety of occupied hours), those savings could be reduced to around zero. However, although measured savings on the plug load operations were minor, the integrated nature of the proposed packages meant this unlocked previously inaccessible energy savings from the overhead lighting system.

In addition, the test results presented here exclude any energy savings potential from daylight dimming (tests were in building interior zone) – including this in applicable zones would further support the economic case for both variants of Technology Package 2. The whole building energy results stated reflect a situation where it is assumed that 100% of the office building is dedicated to office space (i.e. no conference rooms, break rooms etc.).

Table 4: Savings for Task/Ambient Lighting with Plug Load Control

	Retrofit Zone Savings (Large/Small Comm)		Whole Building Energy Savings (Large/Small Comm)
	Lighting and Plug Load Annual Energy Savings %	Lighting and Plug Load EUI (kWh/sqft/yr)	
Tech Package 1 – Basic	33% / 36%	3.16 / 2.8	14% / 18%
Tech Package 2(a) – Adv	30% / 32%	2.82 / 2.52	12% / 16%
Tech Package 2(b) – Adv	38% / 41%	3.61 / 3.23	16% / 20%

All savings are calculated against an existing building baseline equivalent to the 2003 CBECS annual energy consumption for lighting and plug loads (Deru et al. 2011). Energy cost savings using an average utility rate across the POU territories resulted in \$0.45-0.51, 0.41-0.45 and 0.52-0.58 \$/sf/yr for each of TP1, TP2a and TP2b respectively.

Workstation-specific lighting with daylight dimming controls (Developed with Xcel Energy (Colorado and Minnesota))

Previous work (Regnier et al. 2016) described the system selected with Xcel Energy as including a daylight redirecting film retrofit application, coupled with daylight dimming controls. Testing of this system indicated that the film did not result in significant lighting energy savings as installed and commissioned. Investigations revealed that there was potential for energy savings with this technology; however, it would require a degree of customized lighting system design and tuning that was beyond the scope of the 'plug and play' integrated system incentive program. As a result, this system was redefined as a workstation-specific lighting system retrofit, combined with daylight dimming controls.

The key technology features of this integrated system are:

Occupant/Workstation-Specific Lighting: one individual light fixture per workstation. Lighting is designed to provide a reasonable light output at the occupant's workplane (i.e. 300 or 500 lux).

Daylight Dimming Lighting Controls: intelligent granular workstation- specific control through local photosensors tied to the lighting control system. Lighting control responds to available daylight. Illuminance-driven control dims lights continuously based on daylight availability, down to a zero lux light output at full dimming.

It should be noted that workstation-specific lighting systems may also employ occupancy sensors, with one sensor per fixture and occupant. This additional functionality was not evaluated as part of this integrated system package, and test results indicate that for south facing daylit zones this feature would not result in significant, cost-effective additional energy savings. FLEXLAB testing of this system provided savings data based on controlled side-by-side testing compared to the utility baseline over a range of seasonal and test conditions. Testing covered various configurations of lighting types (LED pendant and troffer), light level output (300 and 500lux) and shading configurations (no shades; shades mounted and positioned at various seasonally-determined angles). The major test objectives were to analyze the energy savings impact of the workstation-specific lighting system with daylight dimming controls as compared to the base case condition. An evaluation of the visual comfort and illuminance in the workplane and surrounding areas as compared to the base case condition was also conducted.

The test case (i.e., workstations-specific LED lighting system) and the base case (i.e., T8 lighting, recessed fluorescent troffers and no daylight-based dimming) were tested at the same time under identical conditions using two FLEXLAB testbed cells. Table 5 describes test conditions, and Figure 3 shows the floor plan and external view respectively of the testbed. Each test cell is approximately 20' wide and 30' deep, south facing with good solar access.

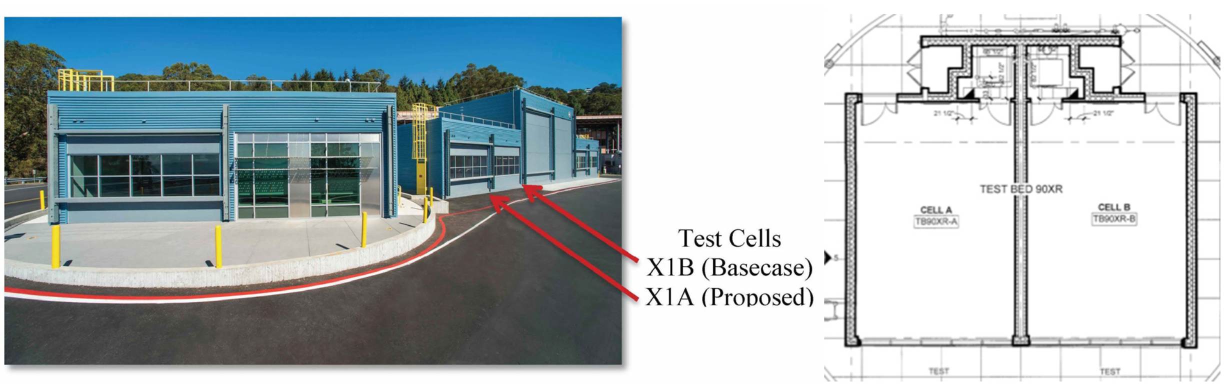

Figure 3: FLEXLAB Test Cells Image & Floorplan, Proposed (Cell A) & Basecase (Cell B).

Table 5: FLEXLAB test parameters

Feature	Base Case Description	Test Case Description
Lighting Fixtures	(6) 2'x4', 3-lamp T8 fluorescent, recessed, parabolic troffers	(6) 4' pendant-mounted, LED direct-indirect luminaires with integral occupancy/photosensors
Light Fixture Layout	10' x 8' spacing between fixture center lines	(6) 4' workstation-specific fixtures centered above workstation task areas.
Light Output Level	[Fixed output fixtures, not tunable]	Workplane light levels were tuned to: A) ~ 300 lux min. (~30 fc) B) ~ 500 lux min. (~50 fc)
Lighting Controls	Scheduled on/off control(7pm to 7am)	Scheduled on/off control(7pm to 7am); dimming all lights throughout day based on available daylight measured by on-board photosensors.
Shading	Venetian blinds in horizontal position. Blade angle adjusted seasonally to direct-sun blocking angle.	Venetian blinds in horizontal position. Blade angle adjusted seasonally to direct-sun blocking angle.

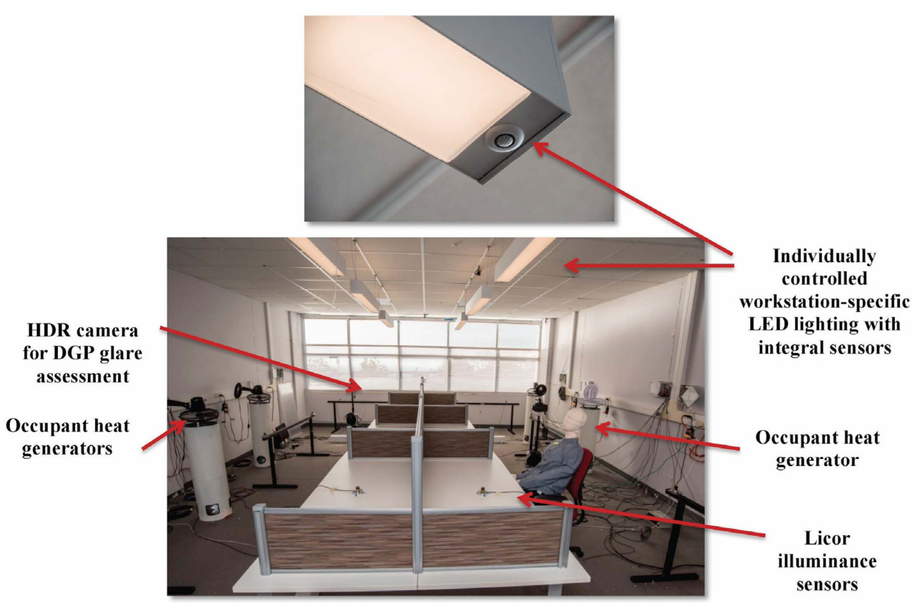

Figure 4: FLEXLAB Internal Test Cell View with Key Features

The lighting energy savings for workstation specific lighting were substantial, varying depending upon available daylight and seasonally, with energy savings FLEXLAB test results ranging from 71-96% daily over the occupied hours in the fall and winter periods. Although not tested throughout the study, a sample result measured under sunny fall conditions indicated ~72% savings for a zonal lighting system, indicating that there may be as much as 20% additional energy savings for the workstation specific lighting system overall a zonal approach. Overall, equivalent annual lighting energy savings for the FLEXLAB testing for 500 lux minimum output conditions translated into a 94% annual energy savings for this system [as applied to TMY conditions in Denver]. When applied to the DOE reference buildings however, this annual energy savings drops to 82% due to lighting usage during unoccupied hours which predominantly do not have daylight harvesting opportunities. Equivalent whole building annual energy savings using the DOE reference buildings are illustrated in Table 6.

Table 6. Workstation Specific Lighting System Whole Building Savings (500lux Case)

Reference Building	Retrofit Zone Savings		Whole Building Site Energy Savings %
	Lighting Annual Energy Savings %	Lighting EUI Savings (kWh/sqft/yr)	
Large Office	82%	3.57	6-15%
Medium Office	82%	3.66	13%

The whole building energy savings range for the large commercial offices is presented for the cases with and without an onsite data center (server room) present in the reference model.

Lessons on Deploying Integrated System Packages

All three integrated systems were brought into their respective utility program planning processes and although each is early in their deployment, several notable lessons have already been identified, some discerned before test completion.

A series of interviews with market stakeholders was conducted by subcontractor DNV GL to gain an understanding of their perceptions on the potential for systems energy savings and for market adoption. The interviewees included utility program managers, policy makers, contractors, architects, engineers, manufacturers, operators, owners and subject matter experts on lighting. In general, they were familiar with these system technologies but lacked an understanding of their energy savings potential and their impacts on building operations and costs. This notable disparity points to a need for further study and education on the benefits and potential impact of integrated systems, as compared to widget based energy efficiency upgrades.

The deployment of integrated systems in commercial buildings were also perceived as involving more rigorous retrofit activities than are experienced in ‘widget’ based equipment replacements. In the case of the three systems studied, this would involve relocating and replacing light fixtures, potentially requiring some ceiling modifications such as installing ceiling tiles. These systems would also involve the installation of interior shades and plug load controls outlets. In contrast with lamp or even fixture replacements, there is an additional level of coordination and potential impact on a building space. For the least disruptive experience, these activities would ideally be timed to occur during a tenant improvement at the time of tenant change, or at the time of sale or purchase of the property timed with move-outs.

In the case of the California POUs, the program manual documentation enabled them to assess their system for inclusion in their Technical Reference Manual (TRM). At the time of writing, the system had been adopted in the TRM, but had not yet entered into their program planning cycle, as the current cycle had yet to complete. However, early feedback indicated that they saw the system most readily being deployed under a direct install program. This strategy is likely a desirable approach for each of the integrated systems to streamline implementation.

Systems Scoping Study - Early Findings

In an effort to better understand current market trends and needs in systems adoption, DOE funded a scoping study to understand what systems the market is current implementing, and provide an indication of system types of strategic interest for further deployment. This work will inform the opportunity space and market for systems deployment. The primary data source utilized is custom utility incentive program project level data. A total of 8 utilities are currently participating, representing more than 18 million customer accounts across the U.S. The utilities include east coast, central, and west coast participants. In addition to these sources, a number of federal programs are providing data related to energy efficiency building retrofits. These include the U.S. General Services Administration's retrofit programs and DOE's Federal Energy Management Program which has a database of thousands of energy efficiency projects. LBNL also maintains a database of energy efficiency projects from the National Association of Energy Service Companies that is in review as well.

Review of these sources to date shows a wide range of detail provided in each program, with controls strategies sometimes described simply as an EMS upgrade, making system retrofit identification a challenge. So far it appears that within custom programs there is a noticeable trend of multiple component based retrofit strategies, such as equipment replacements. Notably they can impact multiple end use systems, e.g. a cool roof or window changeout coupled with a chiller replacement. In some of these cases, there can be interactive savings across these end uses, from the reduction of external or internal heat loads resulting in lower cooling load and energy use for example. It does appear however that the inclusion of integrated system strategies is relatively rare and consequently an opportunity for deeper program savings.

Discussion

The potential for systems to provide deeper levels of energy savings in contrast to single component upgrades in buildings is clearly demonstrated through numerous case studies and evaluations (e.g. Griffith et al. 2007; Regnier et al. 2017), as well as through the evaluations conducted for the three integrated systems packages herein. Test results from the three integrated systems validate their savings potential under a range of conditions, and demonstrated that an integrated systems approach can achieve deep energy savings. Building systems retrofits include a number of opportunities at the end use system level, with levels of complexity and potential energy savings benefits increasing with integration across end uses and potentially with Distributed Energy Resources. However market understanding of the potential for systems energy savings appears to be limited, even among subject matter experts.

As previously reported (Regnier et al. 2016), multiple challenges exist for the successful deployment of integrated building systems. This includes the development of simplified technical approaches for the assessment and implementation of systems. This may involve greater levels of market collaboration across market sectors for the further development of packaged integrated product offerings. The installation of these systems might also span multiple skilled trades, and resources should be considered to enable general contractors and energy service providers to enable streamlined deployment through these existing market channels. Given the lack of knowledge about the energy savings opportunities of integrated systems, further work in developing, packaging, and demonstrating these technologies with significant measurement and verification efforts will be an important step in furthering uptake. Education efforts should also be made targeting trade allies, design firms and owners as well on the opportunities for savings through integrated systems.

In an era of declining energy savings from 'widget' based technologies, and strong mandates for accelerated energy savings, building systems pose a substantial untapped opportunity for deployment, but face a number of challenges such as a lack of industry understanding of savings potential and implementation impacts, and the need for streamlined assessment and deployment methods. In addition, as energy codes have become increasingly stringent the opportunities for utilities to find component level technologies that cost-effectively save energy beyond code has been dwindling. These factors hasten the need for a transition to system-based measures and deployment methodologies.

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