RETROFIT TECHNOLOGY CASE STUDY

nbi new buildings institute

Exterior view of James L. Welch Hall.
Credit: TRC Companies, Inc.

Overview Facts

Location: Carson, California

Size: Building 183,000 sf | Project 131,000 sf

Number of Floors: 4 floors

Construction Type: Existing Building Renovation

Building Type: Office

Construction Year: 2001

ASHRAE Climate Zone: 3B

California Climate Zone: 8

Retrofit Project Team

Owner: California State University, Dominguez Hills Campus

Chief Engineer and Building Manager: Kenny Seeton

Window Shades: Illuminate and Automate by Rollease Acmeda

Lighting Controls: Enlighted

Shade Installer: Lumenomics

Shade Control: BeMotorized

Lighting System Installer: SBT Alliance

HVAC Retro-Commissioning: Taylor Engineering

Building Automated System (BAS) Control Sequencing: Orrovan Mechanical

California State University Dominguez Hills—James L. Welch Hall

California State University Dominguez Hills (CSUDH) is an engaged and collaborative learning community located in the hot, dry climate zone of Southern California.

Welch Hall, built on the campus in 2001, serves primarily as an administrative office building. The four-story rectangular structure has a central courtyard. Elevated corners of the building are primarily curtainwall glass construction, allowing students, teachers, and staff to enjoy the almost year-round sunshine. The building exterior also includes both strip and “punched opening” windows facing all four cardinal directions, including into the center courtyard.

Welch Hall is a mix of open and private office spaces and conference rooms, mediated-instruction classrooms, and computer-based laboratories. It is also a key building for campus operations and administration, housing the CSUDH President, Vice President and Provost offices, the campus police, and the information technology (IT) staff.

Some spaces have a single narrow window, while corner spaces have two full walls of glass. The first floor is partially below grade and houses large, windowless classroom spaces, and office spaces at the perimeter. The second, third, and fourth floors have a mix of private and open offices, conference rooms, and related support spaces.

Research Project Snapshot: Leading in Los Angeles (LiLA)

Research Overview

The Integrated Technologies for Energy-efficient Retrofits (INTER) research objective was to identify an integrated retrofit package that results in a 20% reduction of whole building energy consumption while improving occupant comfort.

The package consists of:

- Advanced lighting and wireless controls
- Automated shading systems powered by photovoltaic cells in all windows but north facing
- Light retro-commissioning of heating, ventilation, and air conditioning (HVAC) systems.

The four-year project launched in June of 2017. Researchers used both laboratory measurements along with two field demonstrations to test technology applications and performance, quantify energy savings, and assess occupant perceptions. The laboratory testing covered a mock-up of three seasons (summer, winter, and spring) at LBNL's FLEXLAB facility. In the lab, daylight glare was carefully measured and was determined to be adequately controlled for all test scenarios and during all seasons.

Energy savings from lighting and HVAC were investigated separately in both the lab and field demonstrations. In the CSUDH site pre-installation, whole-building energy use was collected starting in early 2018 with sub-metering for end uses starting in September 2018. The lighting retrofit began in February 2020, and by the early March 2020 installation and commissioning of the wireless lighting controls were complete. In late March 2020, the space was largely vacated due to the COVID-19 pandemic.

Pre-retrofit occupant surveys helped to quantify occupant perception of their mostly computer-based work environments, but COVID-19 shelter-in-place requirements eliminated the opportunity for a post-retrofit survey. Rather, researchers interviewed a few key staff who remained present in the building to gain an understanding of their perceptions of the building and technologies.

This CEC EPIC research results were shared widely with the commercial real estate industry, architects, engineers, interior designers who specify shades and lighting, building owners and managers, and utility program teams. All the project results and case studies are on the **LiLA web page**.

Project Team:

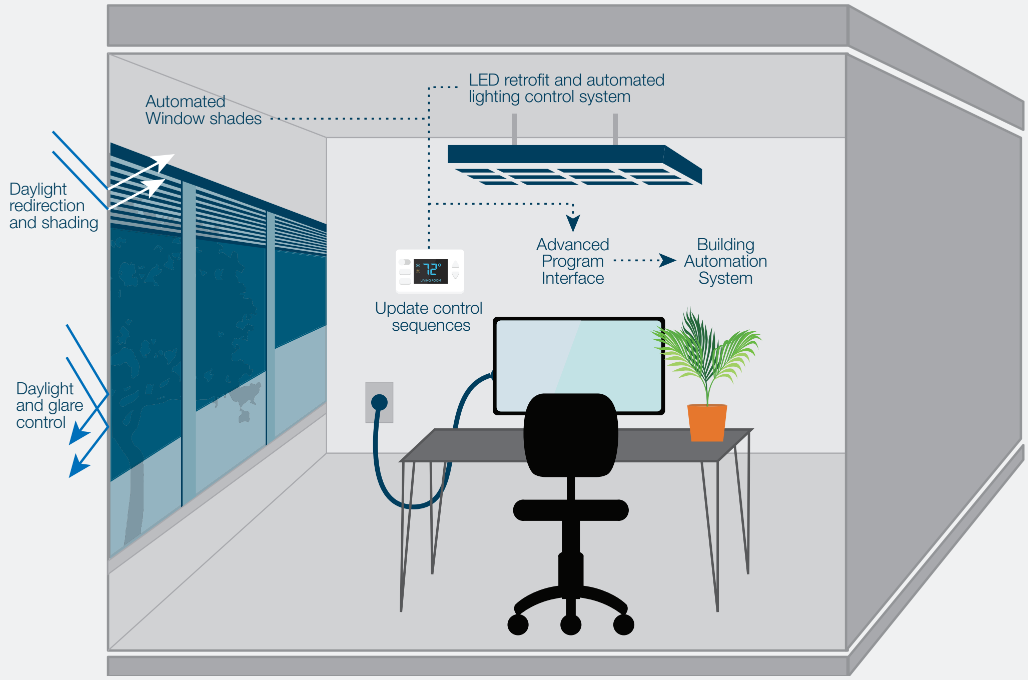
Project Lead: New Buildings Institute (NBI)

Technical Field Demonstration Lead: TRC Companies, Inc.

Lab Test and M&V Lead: Lawrence Berkeley National Laboratory (LBNL)

Manufacturer Partners: Rollease Acmeda, Enlighted

Project Funders: California Energy Commission (CEC) Electric Program Investment Charge (EPIC) program and Southern California Edison



Pre-retrofit Building Conditions

Lighting and Daylighting

Electric lighting in the office spaces consisted of recessed, lensed troffers with T-8 lamps. The lighting zones were organized so that areas could be switched off all together. In addition, a year before this integrated retrofit, Welch Hall had piloted a lighting control system manufactured by Enlighted in about 20% of the building. The early installation, primarily in the hallways and a few office areas, successfully introduced wireless dimming on its existing T8 fluorescent lighting system.

Window Shades

The building has windows facing all four directions, which provided a variety of conditions to test the integrated technology package. Before the retrofit, occupants used manual shades made of typical shade cloth material to block glare and heat gains at certain times of the day. With shades in the closed position to alleviate discomfort, occupants missed the opportunity to see outside views, and access to daylight, two known ways to benefit occupants' wellbeing. The closed shades also eliminated opportunities to harvest daylighting resources, requiring lighting to be on at full power. The increased heat resulting from lighting systems added to the building's cooling demand, causing more energy use than would be necessary if shades were left open during certain times of day.

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HVAC

Welch Hall is served by a variable air volume (VAV) system to meet its heating and cooling needs. Independent of this study, the facility management team had recently installed upgraded VAV controllers to solve for failures in existing equipment. The new controllers enabled the LiLA project team to work with the facility management team on the retro-commissioning aspects of the project (described below).

An open office space with lighting pre-retrofit
Credit: NBI

Retrofit Strategies and Features

Welch Hall was retrofit with the LiLA integrated measure package explained below, which was carefully selected to achieve at least a 20% reduction in whole-building energy consumption while improving occupant comfort.

Lighting and Daylighting

Electric lighting upgrades included LED fixtures, Enlighted wireless integrated lighting controls with updated communications software and hardware, and improved monitoring capabilities. The Enlighted lighting system, known as luminaire-level lighting controls (LLLC), has a wireless sensor and control that allow for fine-tuning at the individual light fixture rather than the zones that were in place before the retrofit.

Window conditions pre-retrofit
Credit: NBI

The LLLC includes sensors that automatically adjust the brightness of individual lamps depending on occupancy and daylight availability. This granular tuning provides just the right amount of light, based on occupant preferences. Upon departure by the occupant, the sensor automatically adjusts settings to optimize energy savings while retaining a balanced illumination across the space. The sensor also communicates with the Johnson Controls building automation system (BAS) allowing for real-time adjustments in the HVAC system based on occupancy, further reducing energy use.

An office hallway with updated LED fixtures, occupancy sensors, wireless communications software and hardware, and improved monitoring capabilities. Credit: NBI

Upper blinds limit daylight while lower shades provide privacy while still allowing a connection to the exterior. Credit: Rollease Acmeda Inc.

Upper blinds direct daylight deeper into the space. The lower shades provide privacy and daylight control. Credit: Rollease Acmeda Inc.

Automated Shading

With windows on all sides, the building offered a unique retrofit and research opportunity for automated shading devices by Rollease Acmeda. Welch Hall was retrofitted with automated window shades designed to optimize visual comfort, thermal comfort, and daylight harvesting for energy savings. The shading system product, called Illuminate, is separated into two distinct parts: an upper blind that directs daylighting and a lower perforated fabric roller shade that provides views when closed and allows occupant control.

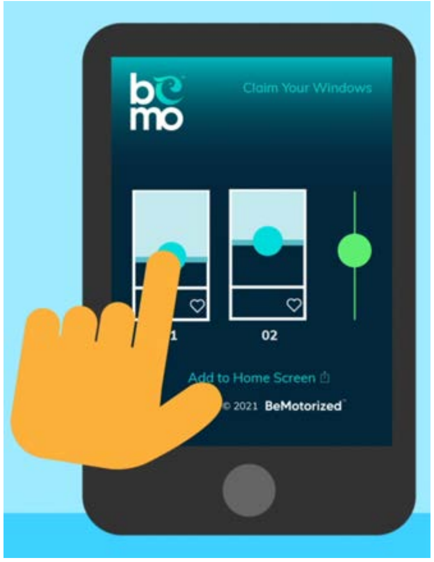
The upper 'daylight' portion of the window shade consists of motorized, louvered blinds. Even with the lower shade closed, the upper blinds redirect light into the space based on daylight availability. An interior daylight sensor on the upper shades determines daylight availability. When appropriate, the blinds automatically reposition to direct daylight deeper into the space. When light bounces off the ceiling, it increases brightness in the space, causing the automated overhead electric lights to dim or turn off completely to maintain preset lighting levels. By reducing the need for lighting, less heat is generated, thereby reducing HVAC loads.

The upper blind and lower roller shade were designed to operate independent of one another. Daylight sensors determine if adequate light is available. If not, they signal to motors, which automatically adjust the upper daylighting blinds to allow light in. An integrated PV panel charges batteries within the shade motor, eliminating the need for wiring.

The lower 'view' portion of the new shades have automated controls. Only a 3% perforation allows for views and connection to the outside. The upper blind and lower roller shade operate independently so even when the lower shade is closed, the upper blinds can continue to redirect daylight into the space. The lower roller shades can be controlled in multiple ways, including:

- Wall-mounted controller switches
- Remote smartphone application
- API software to enable control through the Johnson Controls BAS
- Internal daylight sensor

Building occupants can override the automated shading system using a smartphone app or browser website, which allows them to adjust the shade positioning as needed. Additionally, physical buttons mounted at desks and in common areas allow building occupants to quickly adjust blinds to one of four positions—fully closed, fully open, and two



Occupants can control individual or groups of shades in their space via smartphone app or web browser. Credit: The Energy Coalition intermediate steps between the two. However, the shades reset at the end of each day to provide optimum performance for glare reduction and daylight harvesting based on time of year.

Heating, Ventilation, and Air Conditioning (HVAC)

The project implemented minor retro-commissioning through controls adjustments to ensure HVAC systems function as efficiently as possible and to improve coordination with other installed technologies. Retro-commissioning measures included:

- Programming adjustments for scheduling and controls
- Tuning of temperature set points and nighttime setbacks
- Programming updates for the existing BAS based on ASHRAE Guideline 36 standards for sequences of operation.

The retro-commissioning process is standard practice and a low-cost option to achieve energy savings by bringing the building operations to the latest best practices, particularly for older buildings that have not had any updates since the HVAC system was first installed. The updates of operations in the Johnson Controls system supported the integration of the new occupancy sensors from the Enlighted lighting controls system to enable occupancy-based zone ventilation control.

In existing office buildings, energy performance is influenced not only by the technologies present, but often more so by the facilities staff skills and interest. At Welch Hall, for example, the building manager proactively makes adjustments to the controls and systems to optimize for energy and performance. During the retrofit, he made several additional modifications to further enhance the energy results.

1,989
lighting fixtures upgraded to LEDs and luminaire-level lighting controls (LLLCs)

472
windows have new shades

HVAC system minor commissioning:

Programming adjustments

ASHRAE 36 sequence of operations

Results

Research on the LiLA integrated measures in the laboratory and at Welch Hall demonstrated significant energy savings and multiple other benefits.

Energy Savings

WELCH HALL MEASURED RESULTS

Researchers collected data on the lighting and energy consumption before and after the Welch Hall retrofit project.

The project exceeded the goal of 20% whole-building energy savings, capturing approximately 26% savings in the monitoring and verification analysis period. Welch Hall also demonstrated significant HVAC savings of 29% and lighting energy savings of 35%—compared to the pre-retrofit monitoring period and during the fully occupied period after the retrofit. Unfortunately, COVID-19 pandemic shelter-in-place orders created unusual conditions during part of the monitoring period.

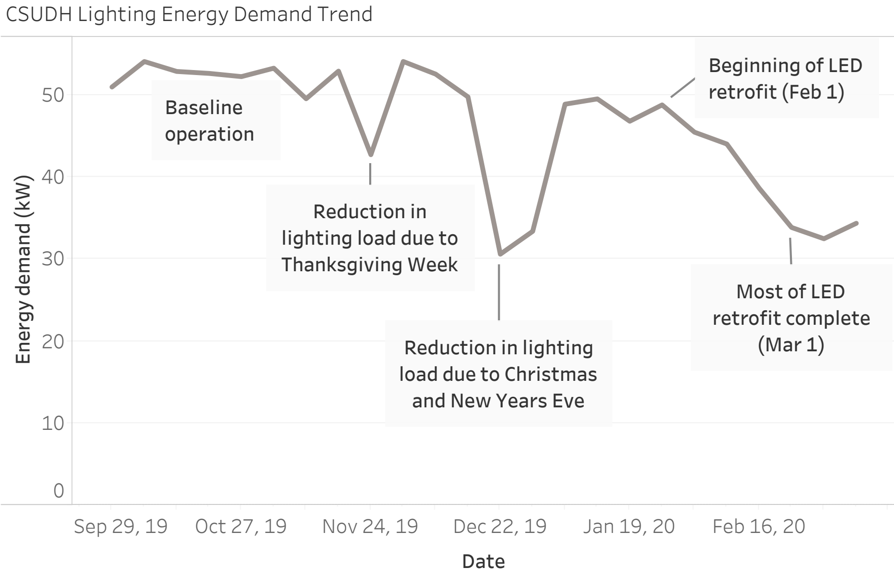
Researchers also investigated pre- and post-retrofit energy demand. Before installation, lighting energy demand data was fairly consistent. Energy demand declined as more lighting fixtures were replaced with LEDs and as the LLLC lighting controls became functional. By October 2019, installation was complete and lighting demand had normalized to a consistent pattern, resulting in a decrease of almost 54% compared to pre-retrofit. The figure below shows average hourly lighting power at Welch Hall from October 2019 through May 2020.

At-a-Glance Energy Savings at Welch Hall:

Category	Percent Savings
Site energy	26%
Electricity	15%
Lighting	35%
HVAC	29%

"The savings is better than I had even hoped for."

Kenny Seeton, Chief Engineer and Energy Manager CSUDH



The Welch Hall retrofit demonstrated an impressive whole-building energy reduction of 26% post-retrofit while fully occupied. The lighting energy reduction was 35% and HVAC 29%. These savings are beyond the project expectations. The new LLLC allow the building manager to use the wireless systems to program and fine-tune the lighting and shades based on occupant needs and available daylight. Occupants can always override the settings to make localized adjustments to accommodate their daily needs.

LABORATORY SAVINGS

Findings from research in the FLEXLAB at LBNL show that in all seasons, the energy impact of the installed technologies at the FLEXLAB was significant. For example, compared to a typical existing office building with T8 lamps, lighting energy savings ranged from 62% in winter to 76% in summer. Increased savings during the summer months is a direct result of additional daylight entering the space and offsetting electric lighting consumption.

Even compared to a new construction office built to the California Title 24 energy standard the savings were compelling, ranging from 50% in winter to 62% in summer. LBNL researchers also found that in warm seasons (summer) for existing buildings the HVAC cooling load was reduced by 36%, and by 28% in the fall. Not surprisingly, HVAC savings from a Title 24 baseline were less, in the range of 15-19% of cooling load. HVAC savings were driven by the reduced heat from the lower-wattage electric light upgrade.

At-a-Glance Energy Savings in the LBNL FLEXLAB

Baseline Comparison	Savings Type	Season		
		Summer	Fall	Winter
Existing Building T8 lamps, 1.0 W/sf, no dimming; manual blinds	Lighting Energy	76%	73%	62%
	Cooling Load	36%	28%	n/a
Title 24 Building T5 (0.69 W/sf); stepped dimming; manual blinds	Lighting Energy	62%	57%	50%
	Cooling Load	19%	15%	26%

NBI research director, Cathy Higgins, examining window retrofits. Credit: NBI

Additional Benefits

The integrated set of measures offer advantages for owners, occupants, and operators.

Owners. The set of energy efficiency measures installed at Welch Hall were an effective way to modernize a building while offering amenities such as localized preferences and controls. Owners also benefit from cost savings resulting from reduced energy use. And, because LED lamps last 2-3 times longer than older T8 or T12 lamps, less staff time is required to switch out lamps.

Occupants. Of the staff remaining in the building during the post-retrofit period occupants appreciated the ability to fine-tune their lighting. They valued the way the automated shading device minimized glare and heat gain. Occupants also valued consistent views to the outside, even with the blinds down.

Operators. With the automated lighting controls and shading system networked into the building's BAS, the facility manager has detailed information on both energy use and occupancy patterns, at the fixture level and by zone. This allowed the operators to gain centralized control over the systems and collect data on preferences, energy consumption, and use patterns within each space. Benefits experienced by occupants may lead to fewer complaints, which is an important benefit to facility managers.

Benefits of Automated Lighting and Shading Systems

Owners
Modernized building
Reduced operating costs
Higher tenant satisfaction

Occupants
Personalized control
Thermal comfort
Elimination of glare
Maintained views

Operators
Centralized data and control
Reduced maintenance of lamp change outs
Reduced comfort complaints

Costs

Construction & Design Costs

The cost of the integrated system retrofit, including the LLLC, automated shades, and light HVAC retro-commissioning was approximately $11 per square foot. The wireless lighting control cost $5.46 per square foot. Square footage of window area is a more typical figure, but the research project had extensive variables. So, the estimates are for the building area—at $4.56 per square foot, including equipment and installation costs. Note: These costs are illustrative and not reflective of costs for this project.

Typical Cost per Square Foot	
Lighting and Controls	$5.46
Shades equipment	$2.24
Shades installation	$1.34
Shades controls	$0.67
Wiring	$0.31
Shades Total	$4.56
HVAC Retro-Commissioning	$0.48
TOTAL	**$10.50**

Note: These costs are illustrative and not reflective of costs for this project.

Conclusion

The Welch Hall retrofit demonstrated an impressive whole-building energy reduction of 26% post-retrofit while fully occupied. The lighting energy reduction was 35% and HVAC was 29%. These savings are beyond the project expectations. The new LLLC allow the building manager to use the wireless systems to program and fine-tune the lighting and shades based on occupant needs and available daylight. Occupants can always override the settings to make localized adjustments to accommodate their daily needs.

Furthermore, the centralized default settings are continually improved based upon their choices.

Having the blend of occupant direct control of thermal and visual comfort, and building manager control of centralized settings and connected information on technology performance and settings, assures a workspace that fits today's workers and optimizes data and performance. The integrated automated shades, LLLC, and minor retro-commissioning upgrade at Welch Hall makes this building contemporary and responsive to today's tenants and sustainability goals.

The LiLA research project demonstrates opportunities for achieving significant energy savings through building upgrades. In California, the retrofit market is massive with existing commercial office buildings representing 22% of the total state's commercial floor space and 27% of commercial energy consumption—more than any other sector. With widespread adoption, the measure packages studied have the potential to help owners save and make money, occupants be more comfortable, and society meet goals for carbon reductions associated with energy generation.

Keys to Success in Integrated Building Upgrades

- **Focus on occupant improvements.** Identify needs that are not currently being met by the building.
- **Convene and engage stakeholders early.** Include the IT department, facilities managers and other building management staff, and key occupants. Communicate the benefits of the new systems to create buy-in from occupants.
- **Maximize savings by packaging measures.** Combining HVAC retro-commissioning, lighting upgrades, advanced lighting controls, automated shading, and other advanced technology solutions saves costs and time.
- **Engage a single entity to lead the project.** Finding one company to provide turnkey design, installation, commissioning, and long-term support for maintaining systems reduces costs, hassle, and time.

New Buildings Institute (NBI) developed this case study.

This work is supported by the California Energy Commission EPIC Program and Southern California Edison (SCE).

EPIC invests in scientific and technological research to accelerate the transformation of the electricity sector to meet the state's energy and climate goals.

SCE funding for research on these technologies is aligned with their Going [carbon] Neutral Pathway 2019 goals and steps.

Program Information

Southern California Edison's Energy Express and Customized Solution Programs offers incentives.

Other California utilities also have programs for upgrading to advanced technologies. Check your local utility web site.

NBI Program Information

info@newbuildings.org

Read More: Leading in LA

New Buildings Institute (NBI) is a nonprofit organization driving better energy performance in buildings. We work collaboratively with industry market players—governments, utilities, energy efficiency advocates and building professionals—to promote advanced design practices, innovative technologies, public policies and programs that improve energy efficiency and reduce carbon emissions. We also develop and offer guidance and tools to support the design and construction of energy efficient buildings. Learn more at newbuildings.org