



**EFFICIENT AND
HEALTHY SCHOOLS**

2022/23 Efficient and Healthy Schools Webinars

Lighting Retrofits for Schools

U.S. Department of Energy and Lawrence Berkeley National Laboratory

Oct 27, 2022

Efficient and Healthy Schools Campaign Webinar

Welcome!

- Agenda is in the chat and on our website
- Webinar is being recorded, and will be posted
- All attendees are muted during this webinar
- Please enter questions into the chat or Q&A at any time
- We will send out the slides and presentation recording shortly after the webinar



Today's Agenda

- Efficient and Healthy Schools Campaign – Alexandra (Allie) Johnson, LBNL
- **Lighting Retrofits for Schools:**
 - Jordan Shackelford, Principal Scientific Engineering Associate, LBNL
 - Axel Pearson, Energy Efficiency Project Manager, PNNL
 - Brief Q&A with school district lighting project, Holt Public Schools
- Q&A. You can also send questions to EHSC@lbl.gov if we are unable to answer them
- Closing and helpful links - Allie Johnson

Efficient and Healthy Schools Campaign

- The campaign aims to: Improve energy performance, reduce carbon emissions, and promote a healthy learning environment in schools.
- The campaign engages K-12 schools especially those serving low-income student populations and in rural areas.
- This campaign is led by the U.S. Department of Energy with technical support from Lawrence Berkeley National Laboratory.

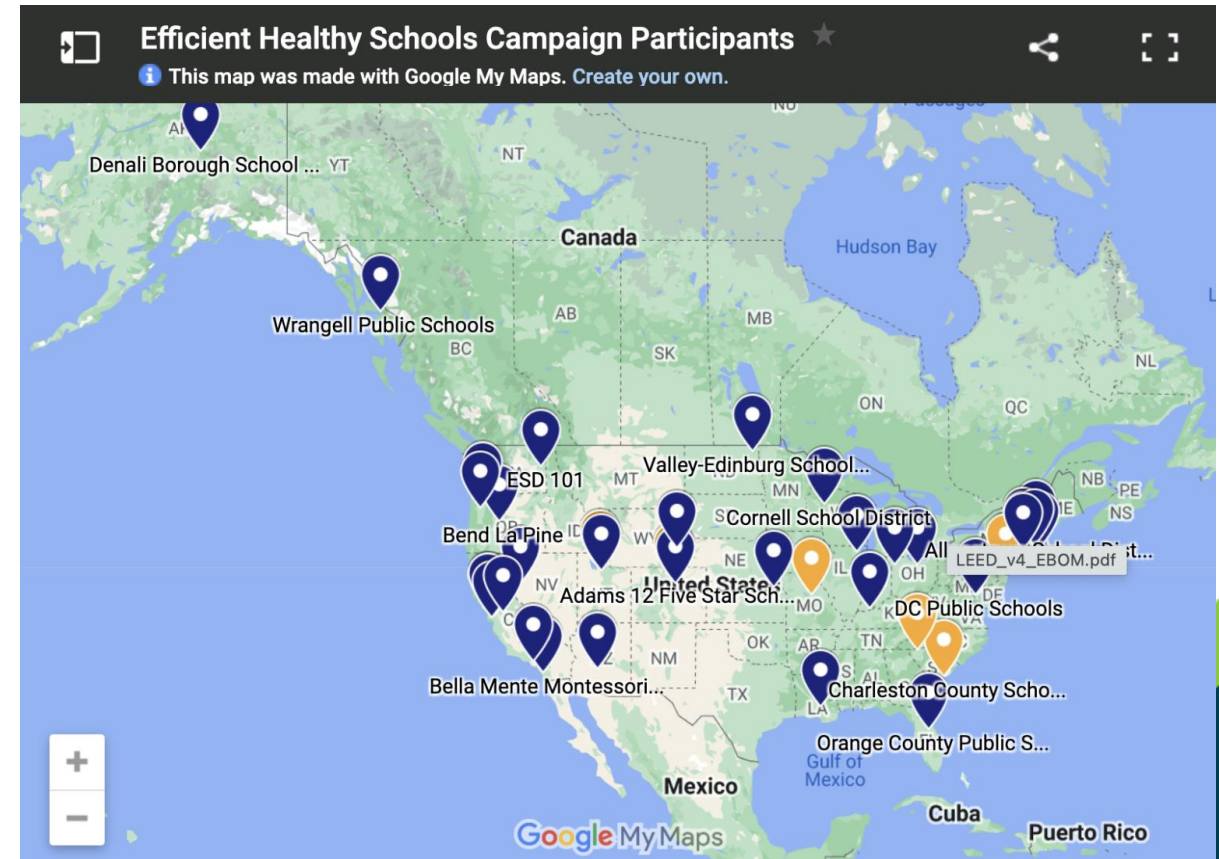


Organizing partners:



Become a Participant or Supporter

- [Campaign participants](#) (such as schools and school districts) can:
 - Access technical assistance and resources on best practices, guidance, case studies, and webinars
 - Receive recognition for their efforts to improve energy performance, health, and resilience
- [Campaign supporters](#) (such as contractors and government) are encouraged to share and promote goals and benefits of efficient and healthy schools



Recognition Program: 2022/23 Second Round!

The campaign will recognize solutions and efforts (implementation or planning) by K-12 schools and districts in the following categories:



Energy Efficiency Plus Health - For improving energy efficiency and indoor environmental quality (IEQ: indoor air quality, lighting, thermal comfort, acoustics)



Emissions Reduction and Resilience - For reducing carbon emissions and improving resilience

Title I schools, rural schools, and schools in disadvantaged communities are especially encouraged to apply.



**EFFICIENT AND
HEALTHY SCHOOLS**

Lighting Retrofits

Technology, resources, M&V, lighting and health

U.S. Department of Energy and Lawrence Berkeley National Laboratory

Jordan Shackelford, Principal Scientific Engineering Associate (LBNL)

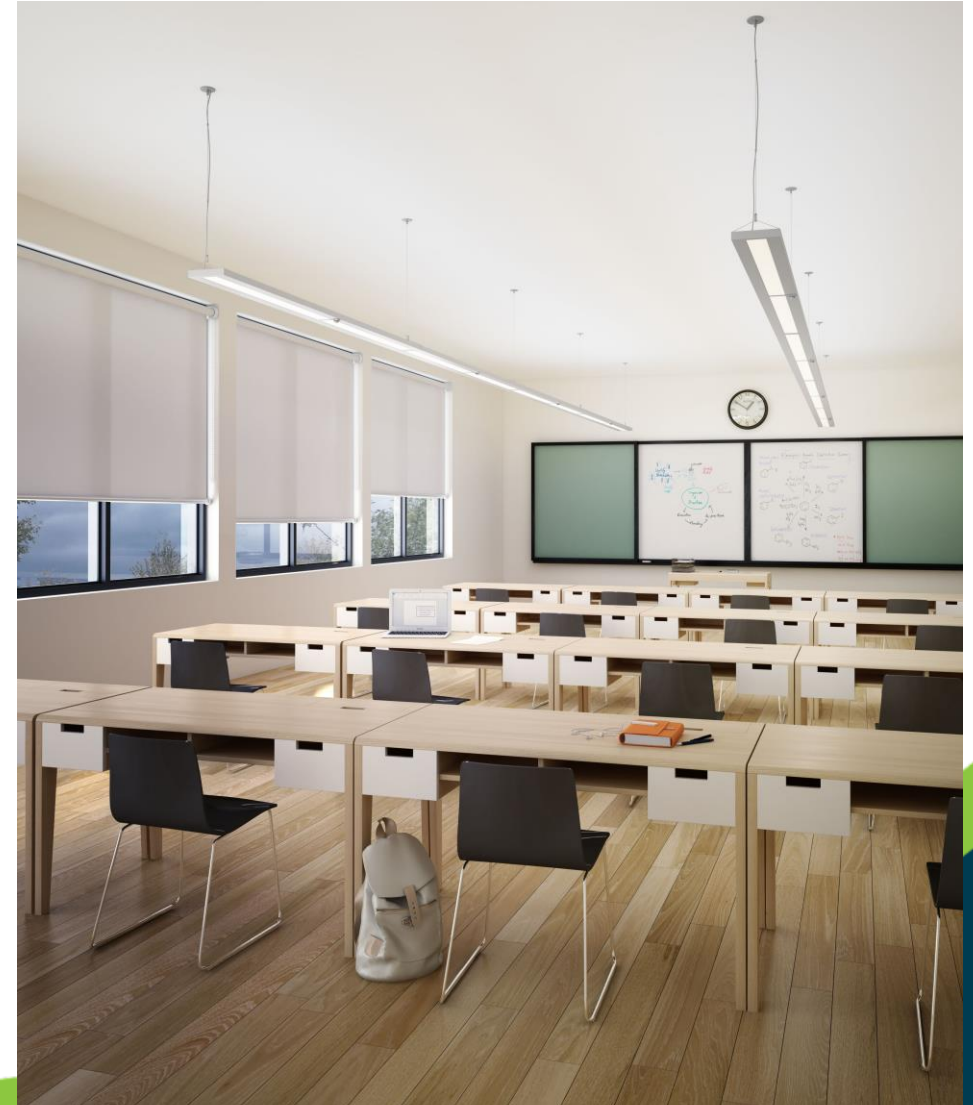
jshackelford@lbl.gov

Where lighting and health fit into EHSC recognition this year



Category:
Energy Efficiency Plus Health

... improving **energy efficiency** and
indoor environmental quality
(indoor air quality, **lighting**, thermal
comfort, and/or acoustics)



What does lighting provide in the learning environment?

- Visual acuity and performance
- Ambience
- Windows: daylight, views, connection to natural world
- Circadian phase setting, alerting effects
- Distinguish colors and hues
- Wayfinding
- Exterior / security lighting can discourage theft, vandalism, unauthorized use of school grounds



Security and safety, indoor air quality, thermal comfort, visual comfort, and acoustic comfort conditions affect attendance, teacher turnover rates, and occupant health

What does lighting cost schools?

- K-12 schools spend \$8 billion+ annually on energy, 2nd highest expense behind salaries
 - More than computers, textbooks combined
 - Lighting energy: ~19% of budget (\$1.5B!)
- Average age of U.S. public schools: 44 years
 - Lighting systems often outdated, contributing to user dissatisfaction



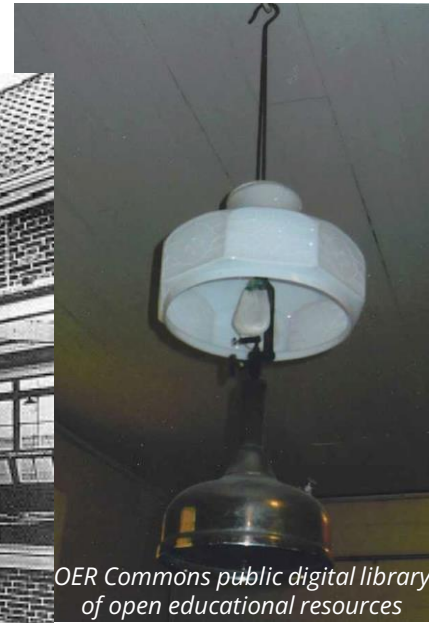
Coronet LED
<https://www.pinterest.com/pin/978266350283204612/>



Trends in lighting technology

A little historical context

- 1850s: Camphine oil, lard oil, kerosene, whale oil!
- Early 1900s : large windows, daylight dependence
 - Southern orientation, with folding or sliding windows
 - High-reflectance walls and ceilings
- Oil lamps replaced with electric lamps in 1930s
- Late 1960s: 'efficient' fluorescent lighting reduced focus on daylight
 - Prevalence of air-conditioning led to smaller / fewer windows for energy savings (1970s energy crisis...)



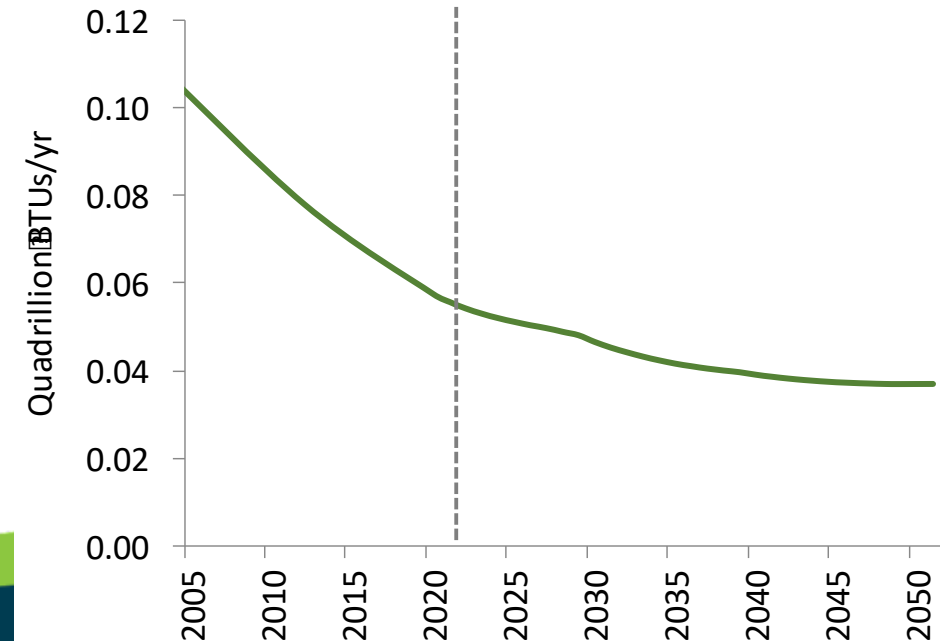
Evolution of light source technologies

- Incandescent
- Halogen
- Compact Fluorescent Lamp (CFL)
- Linear Fluorescent
- High-Intensity Discharge (HID)
- Light-Emitting Diodes (LED)



<https://lumenow.org/choosing-a-bulb/>

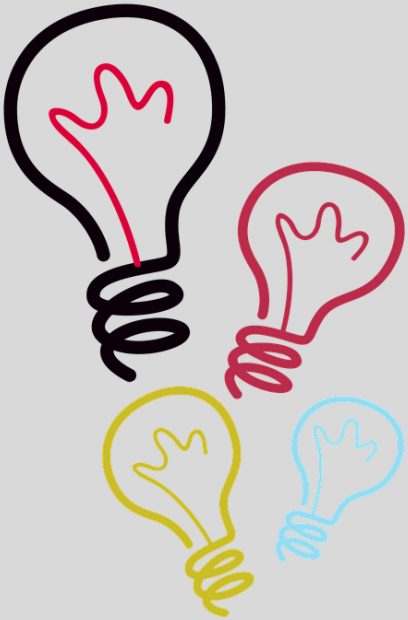
Annual Energy Usage for Lighting in Schools



Adapted from [Shackelford and Safranek ACEEE summer study 2022](#)

LED advantages

**Wide
Functionality**



**Energy/Cost
Savings**



**Low
Maintenance**

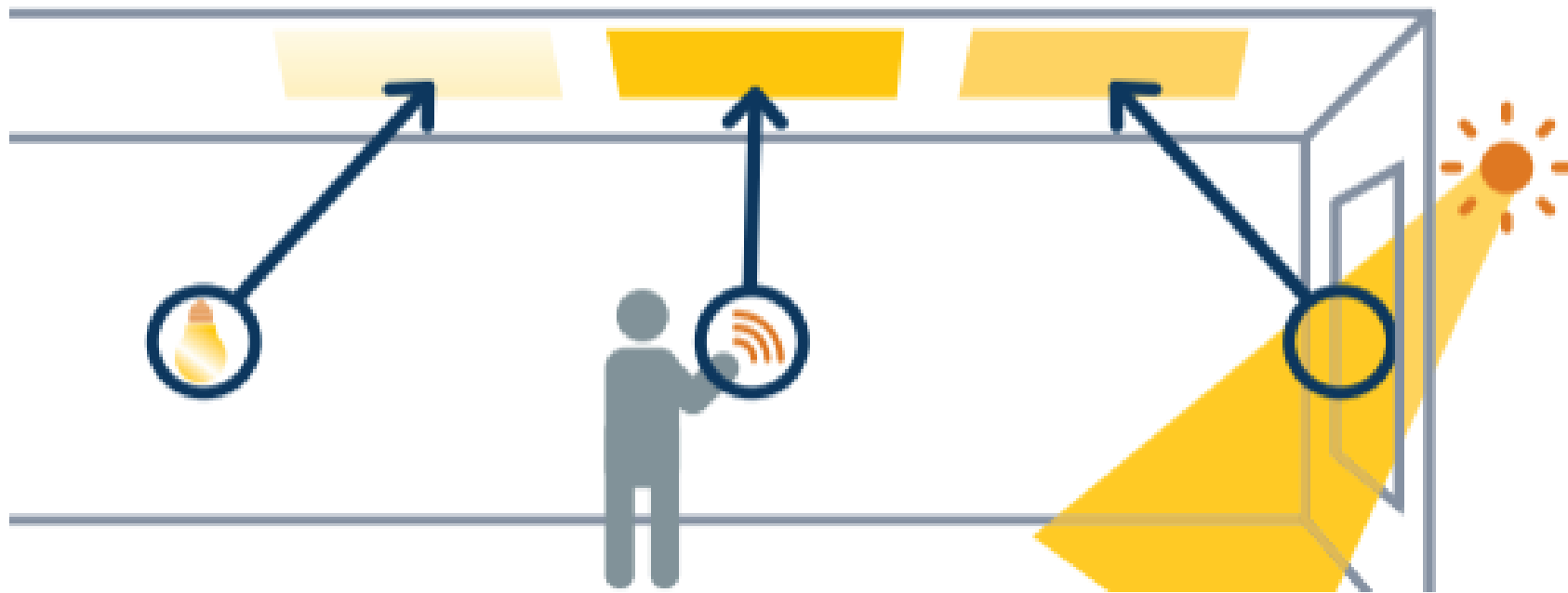


**Environmentally
Friendly
Materials**



LEDs also enable efficient lighting controls strategies

LIGHT-LEVEL TUNING, OCCUPANCY SENSING, DAYLIGHT HARVESTING



Modern lighting controls

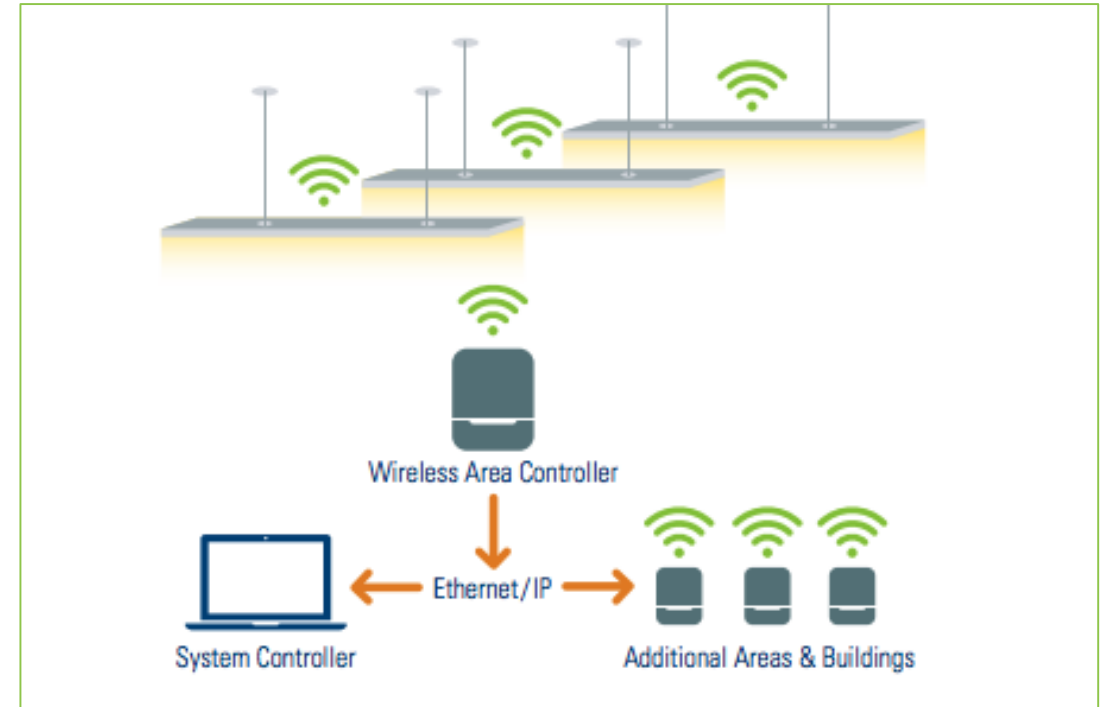
Go by many names / flavors...

Advanced Lighting Controls (ALCs)

Networked Lighting Controls (NLCs)

Luminaire-Level Lighting Controls (LLCs)

- Potential features of 'connected' controls:
 - Zonal or fixture-level occupant/daylight detection
 - Automatic scheduling, switching, dimming
 - Networked controls can integrate with HVAC, fire/security, and other building systems
 - Energy monitoring
 - Demand response
 - Color temperature tuning ("warm" vs "cool" light)
- In over 1/3 commercial installations by 2035
- Rebates available for advanced lighting controls



2015 Wireless Advanced Lighting Controls
https://www.gsa.gov/cdnstatic/GPG_022-Wireless_ALC.pdf

Lighting retrofit opportunities

Basically wherever there are lights!

- Classroom
 - Office / administration
 - Hallway and stairwell
 - Gymnasium, auditorium, and other high-bay applications
 - Parking garages and lots
 - Exterior wall luminaires/wall packs, site lighting
- Don't forget controls opportunities!



Axis Lighting

<https://www.pinterest.com/pin/807199933209163959/>



Daylighting In The Classroom



Resources

Efficient and Healthy Schools Campaign resource page links to all of the following, at <https://efficienthealthyschools.lbl.gov/resources>

Resources: [Better Buildings K-12 Lighting Toolkit](#) and the [EHSC Resources Page](#)

Case Studies

- How other schools approached challenges

Design Guides

- Considerations for specific applications and approaches

Fact Sheets

- Application-specific guidance

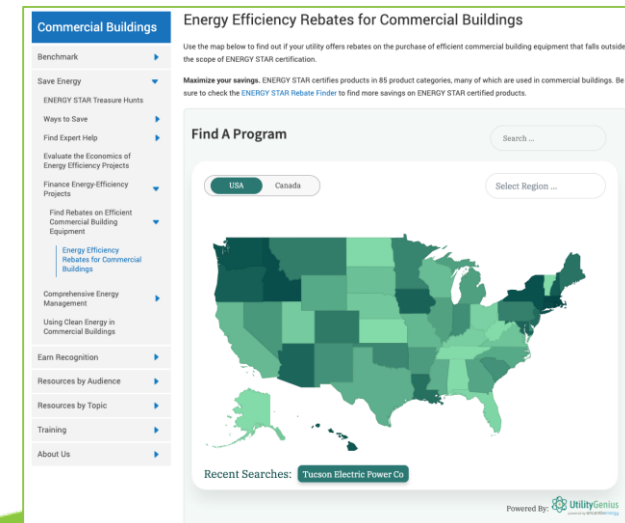
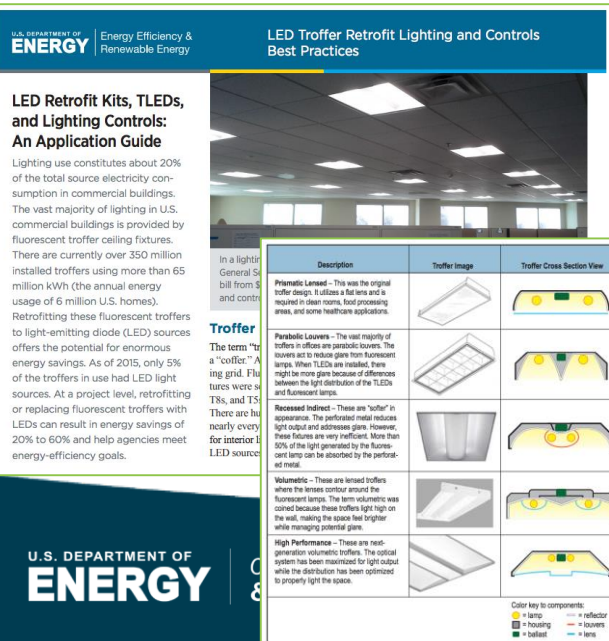
Reports

- Technical, research-oriented facts on lighting upgrades

Specifications

Videos and Webinars

ENERGY STAR Utility Genius Rebate Finder

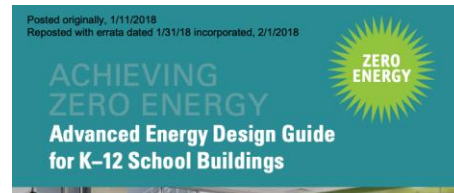



LED Retrofit Kits, TLEDs, and Lighting Controls: An Application Guide

Lighting use constitutes about 20% of the total source electricity consumption in commercial buildings. The vast majority of lighting in U.S. commercial buildings is provided by fluorescent troffer ceiling fixtures. There are currently over 350 million installed troffers using more than 65 million kWh (the annual energy usage of 6 million U.S. homes). Retrofitting these fluorescent troffers to light-emitting diode (LED) sources offers the potential for enormous energy savings. As of 2015, only 5% of the troffers in use had LED light sources. At a project level, retrofitting or replacing fluorescent troffers with LEDs can result in energy savings of 20% to 60% and help agencies meet energy-efficiency goals.

Description	Troffer Image	Troffer Cross Section View	TLED	Kit
Planaric Lenses - This was the original troffer design. It offers a flat lens and is required in clean rooms, food processing areas, and some healthcare applications.			●	●
Parabolic Louvers - The vast majority of troffers in use are parabolic louvers. The louvers act to reduce glare from fluorescent lamps. When TLEDs are installed, there might be more glare because of differences between the light distribution of the TLEDs and fluorescent lamps.			▲	●
Recessed Indirect - These are "soft" in appearance. The perforated metal reduces light output and addresses glare. However, these fixtures are very inefficient. More than 50% of the light generated by the fluorescent lamps can be absorbed by the perforated metal.			▲	▲
Volumetric - These are lensed troffers where the lenses control the light from the fluorescent lamps. The term volumetric was coined because these troffers light high on the wall, making the space feel larger while managing potential glare.			●	●
High Performance - These are next-generation volumetric troffers. The optical system has been maximized for light output while the distribution has been optimized to properly light the space.			●	●

Color key to components:
■ = lamp ■ = reflector
■ = housing ■ = louvers
■ = ballast ■ = lens
● = few limitations
▲ = proceed with caution



ACHIEVING ZERO ENERGY Advanced Energy Design Guide for K-12 School Buildings

Posted originally, 1/11/2018
Reposted with errata dated 1/31/18 incorporated, 2/1/2018

ZERO ENERGY



LIGHTING RETROFIT STRATEGIES FOR CALIFORNIA SCHOOLS

GYMNASIUM (K-12 INSTITUTIONS)
LED HIGH BAY

THE OPPORTUNITY
Provide high-quality lighting that illuminates the gymnasium floor area to recognized light level standards, and meets or beats the local energy codes. LED sources offer instant full brightness and significant longevity. When used in conjunction with an appropriate control system, the fixtures can be dimmed to allow the gymnasium to be used for other assembly functions.

THE SOLUTION
Install industrial LED high bay luminaires on 25' x 25' centers. Fixture options allow for integrally mounted occupancy sensors, photo cells, emergency lighting and dimming. It should be noted that the highest light levels are required at the playing area, while the spectator area requires less light.

DESIGN CONSIDERATIONS
In this application the emphasis is not only on appropriate horizontal and vertical illumination, but also on uniformity. This layout achieves a desirable contrast ratio of less than 3 to 1. Note: Recommended light levels for collegiate facilities and televised events are significantly higher than for K-12 institutions.

Resources: Performance criteria for schools

... beyond energy code (lighting power density (W/ft²), lumens per watt)
and illuminance criteria (foot-candles, uniformity ratios)

Collaborative for High Performance Schools

- Indoor Environmental Quality Credits for Daylight: Glare and Availability, Views, Electric Light Performance, Circadian Lighting



Illuminating Engineering Society Recommended Practice

- Lighting Educational Facilities (RP-3-20)



LEED v4.1 Building Design & Construction

- EQ Credits for Interior Lighting, Daylight, Quality Views



Design Lights Consortium

- Fixture and networked controls criteria

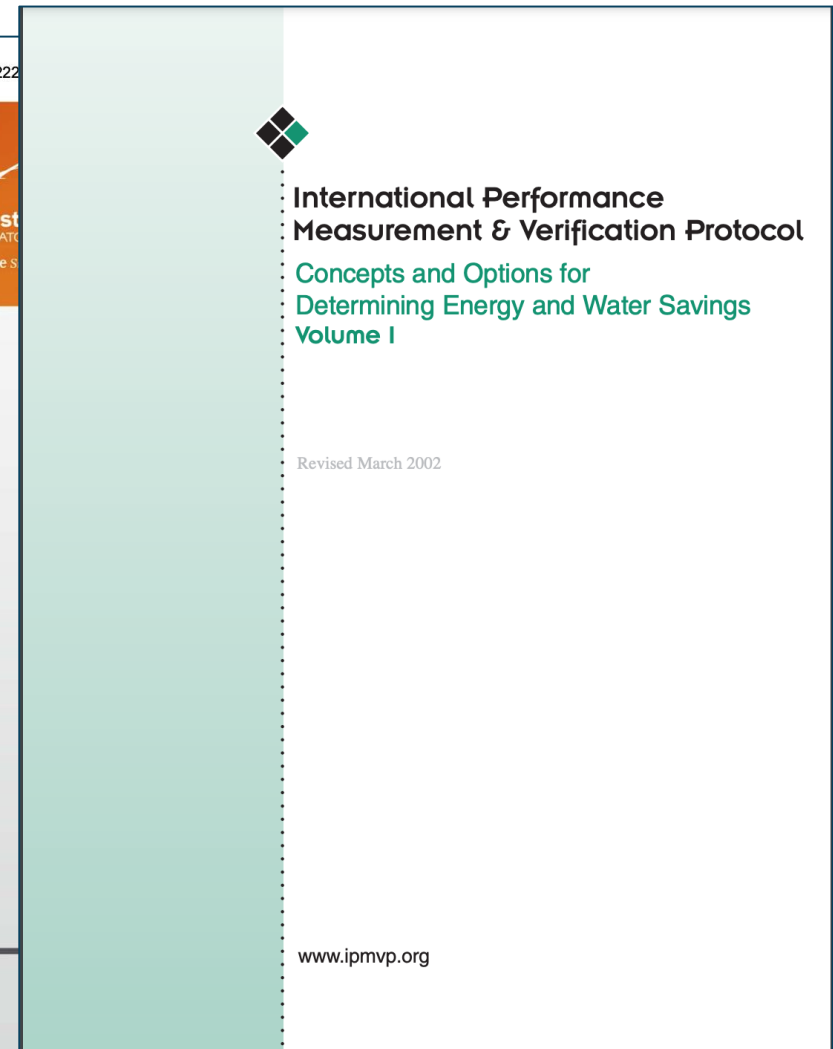
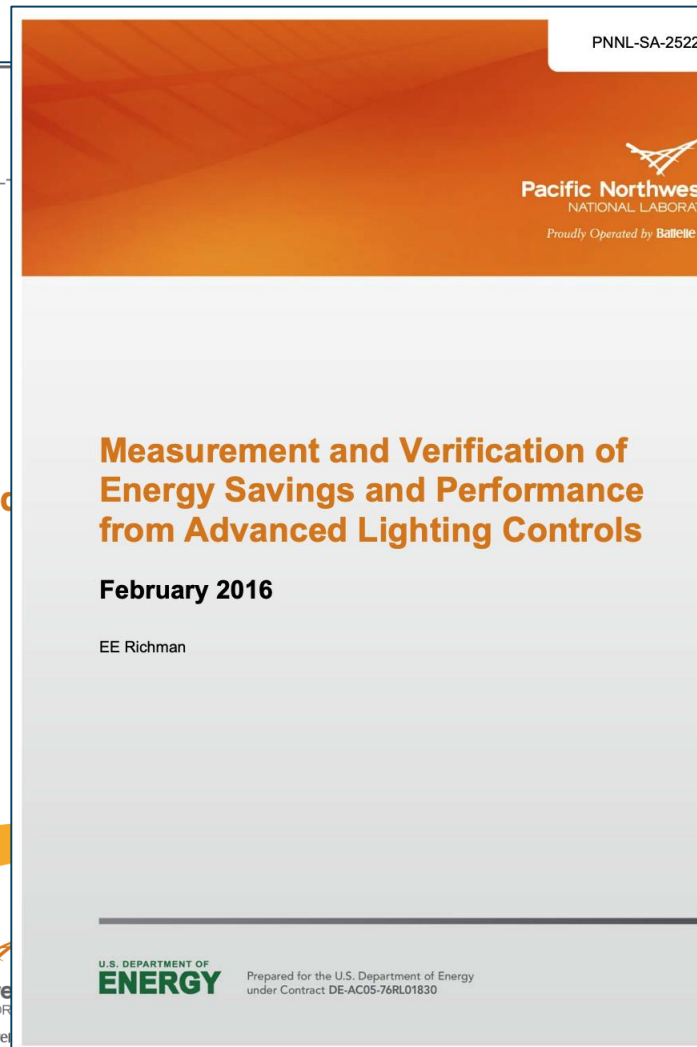
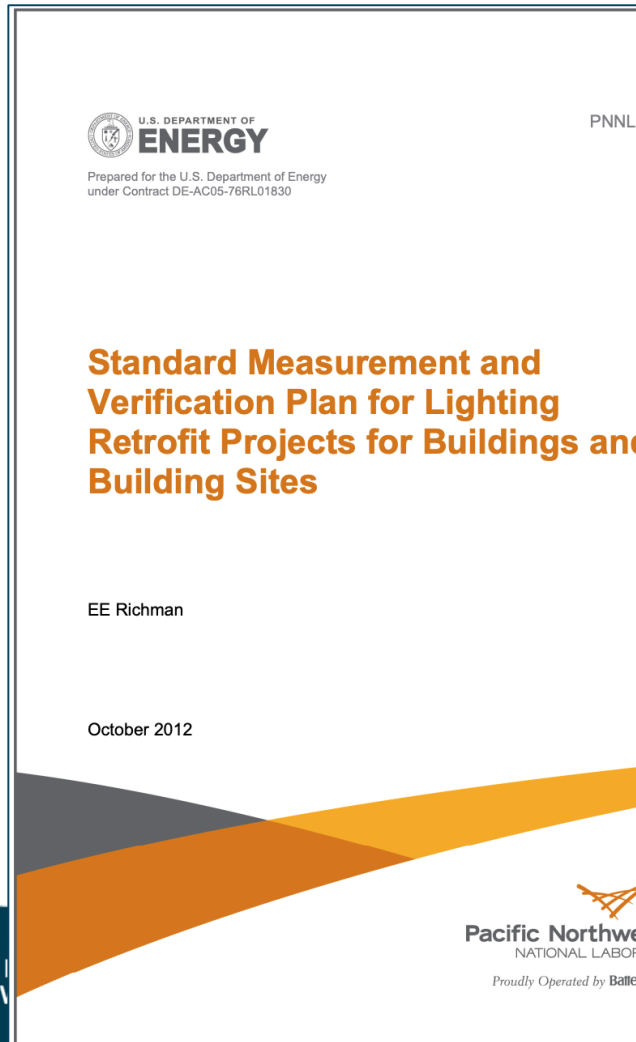


Achieving Zero Energy: Advanced Energy Design Guide for K-12 School Buildings

- Visual Comfort, Daylighting, Glare, Electric

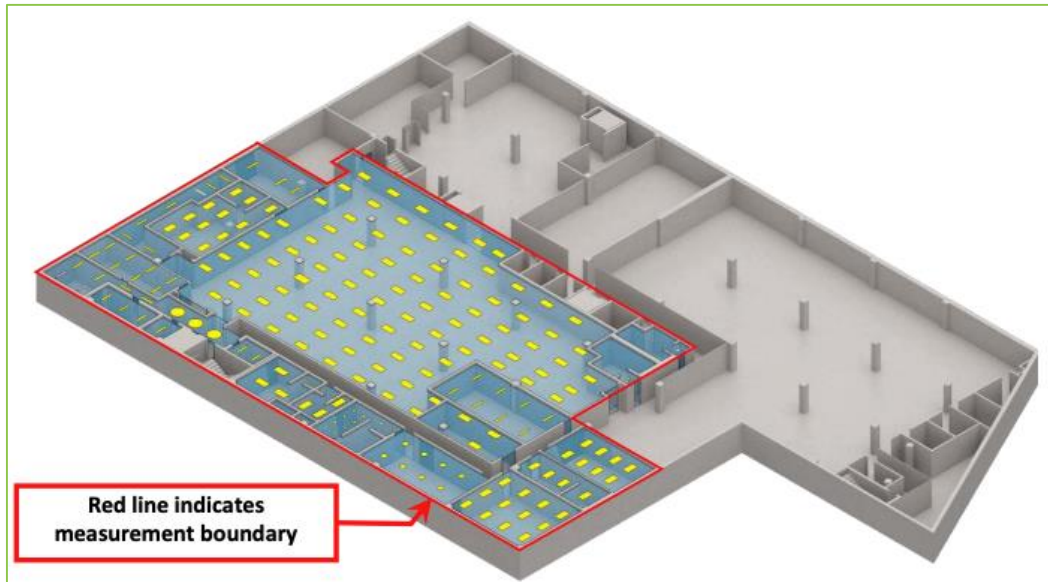


Resources: Measurement and verification manuals



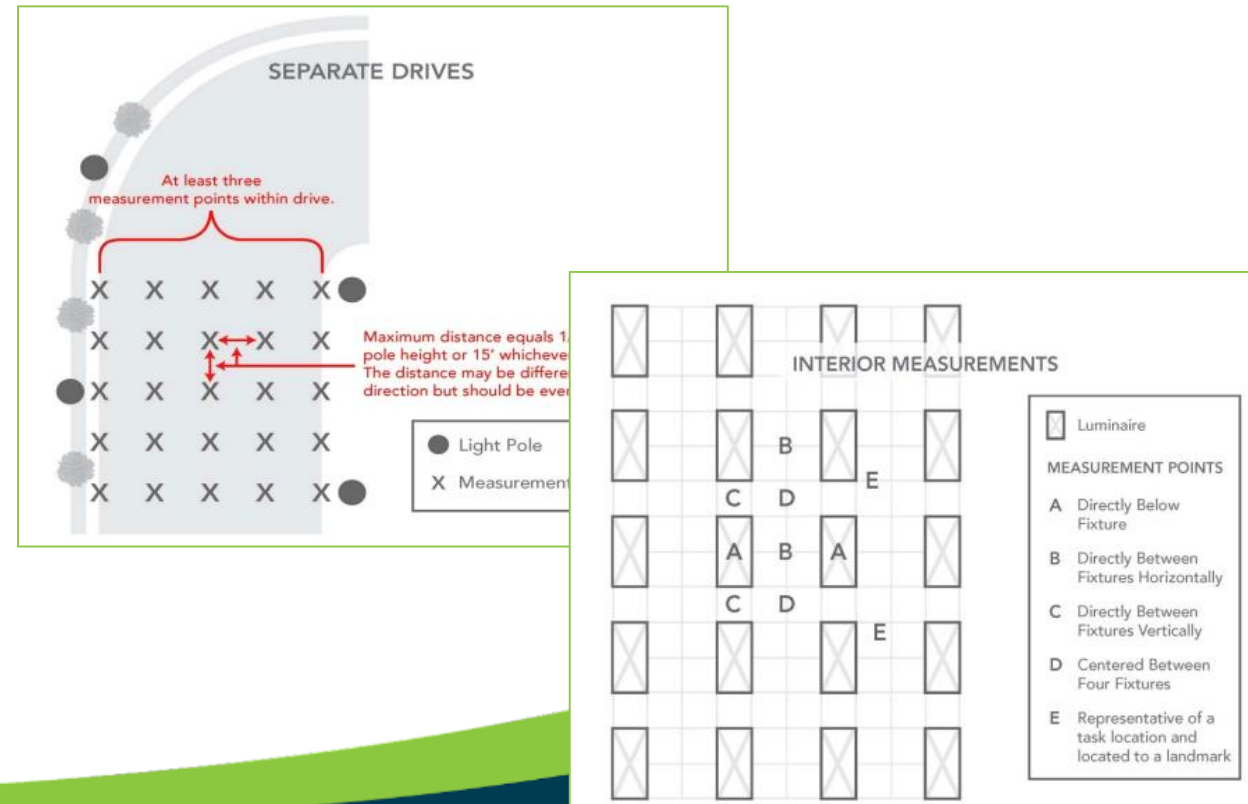
Resources: Measurement and verification

Energy Performance



Measurement Guide: Lighting on Dedicated Panelboards Without Automatic Controls. Building Performance Lab CUNY. 2020 <https://www.cunybpl.org/wp-content/uploads/2020/12/Lighting-Measurement-Guide-DWoC.pdf>

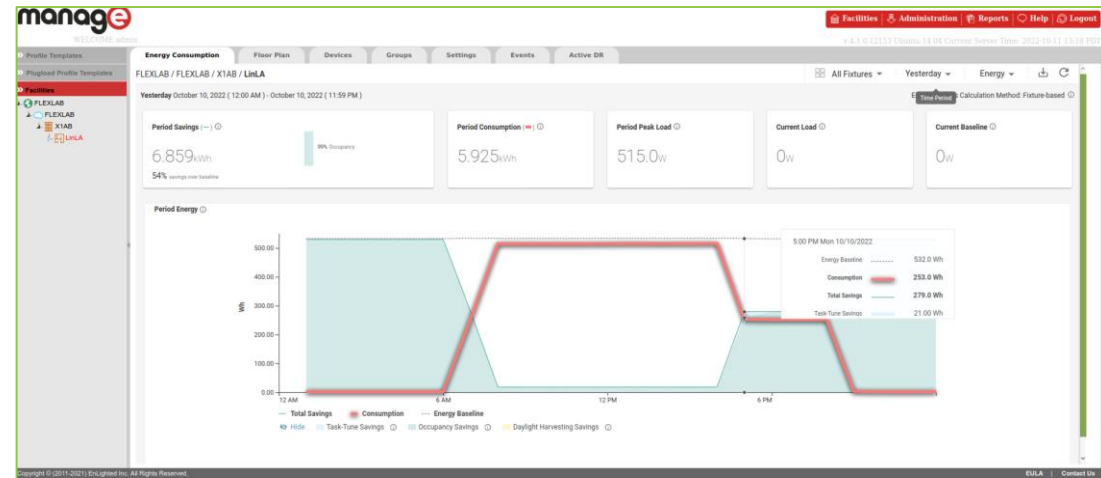
Lighting Performance



Measurement and verification

IPMVP M&V: Options A, B, C, and D

- | | |
|---|---|
| <p>A Estimations from data, equipment specs, engineering calculations</p> | <p>C Measurements at whole facility or sub-facility level (incl. utility meter)</p> |
| <p>B Field measurement of system energy use</p> | <p>D Computer simulation (whole facility, sub-facility)</p> |



- Energy performance
 - Calculated (method A): works when no operation changes are made (e.g. LEDs but no controls changes)
 - Measured (methods B/C): at panel, meter, or trended by controls
- Lighting performance
 - Often assumed to meet standard based on retrofit design / specifications rather than field verified
 - Daylighting performance: often easier simulated than measured
- Important: Work with funding agency, utility program, involved party on M&V plan before retrofit



Lighting and Health

Health and safety implications of lighting in schools

- Good lighting design can improve health, learning, visual connection with environment, and decrease absenteeism. Exterior lighting illuminating surfaces and corners, especially combined with occupancy sensor control, can enhance safety and discourage theft and vandalism ^{1, 2, 3}
- Different color temperatures, brightness levels can effect concentration, alertness, and calmness ^{4, 5}
- Statistical connection between daylighting and performance in schools ⁶
- The lighting environment is fundamental for circadian health and “entrainment” ⁷



Health and lighting in schools: GATEWAY Pilot Studies Evaluating Tunable LED Lighting

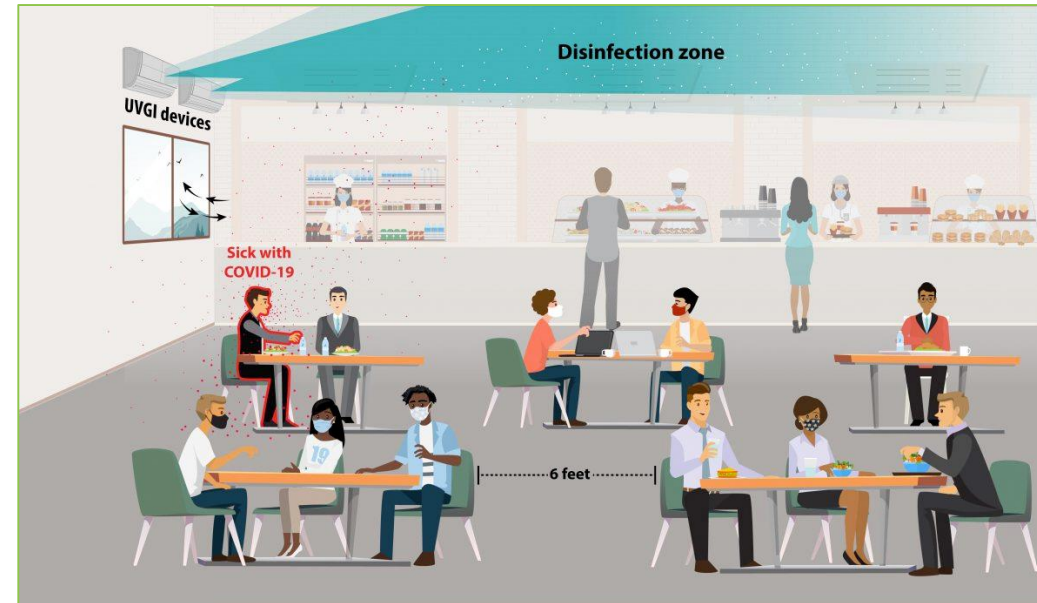
- Lighting and circadian health
 1. Light exposure and melatonin regulation linked
 2. Human circadian system more sensitive to blue wavelengths more prevalent in higher “cool” CCTs
 3. Color temperature tuning may affect lighting system circadian performance
- The tunable systems studied here achieved 45-60% energy savings
 - From LEDs and dimming controls, not color temp. tuning
- Justification for tuning controls: Non-Energy Benefits
 - Give teachers more control of classroom environment
 - Improve student engagement
 - Controlling brightness and color temp. may help meet circadian performance targets (e.g. CHPS criteria)



<https://betterbuildingsolutioncenter.energy.gov/sites/default/files/attachments/2017-TunableLightingFarmersBranch.pdf>

Health and Lighting: Germicidal UV

- Used as early as 1930s in schools to deactivate pathogens
- Another strategy to reduce transmission is increasing ventilation or outside air levels
 - But, for equivalent disinfection potential, GUV may be more energy-efficient
- See ongoing DOE / PNNL research on this important (re)emerging technology!
<https://www.energy.gov/eere/ssl/germicidal-ultraviolet-disinfection>



<https://www.cdc.gov/coronavirus/2019-ncov/community/ventilation/uvgi.html>



Questions?

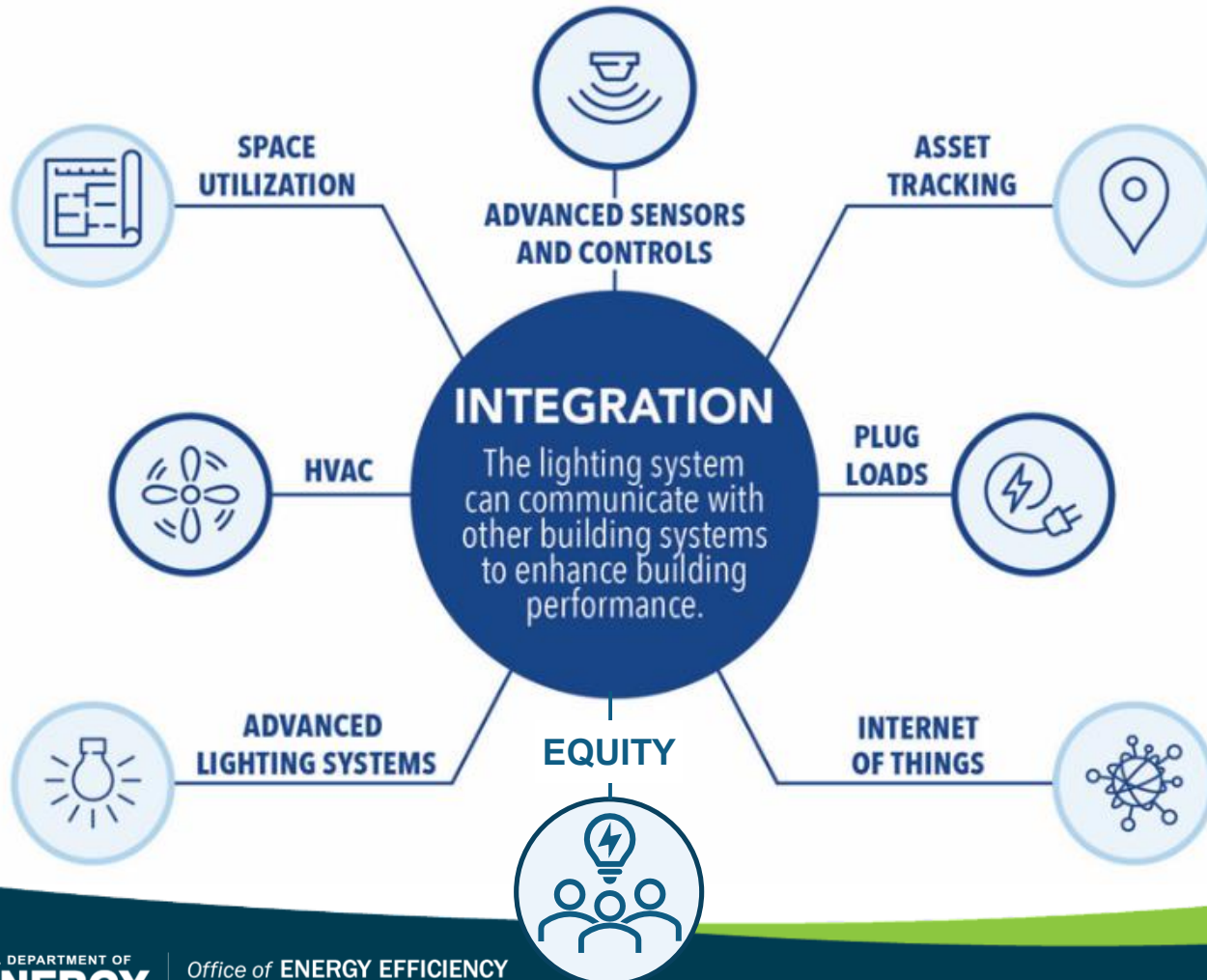
Contact us at EHSC@lbl.gov



Integrated Lighting Campaign



Overview – Integrated Lighting Campaign



- The ILC recognizes innovative lighting projects in 6 categories, including:
 - Advanced sensors and controls
 - Integration with HVAC, plug loads, and other building components
 - Cutting-edge IoT capabilities like asset tracking and space utilization
- Supporters can be recognized in 2 categories, as well

ILC Organizing Committee



- The ILC is a collaboration between 7 Organizers
- The Organizing Committee provides guidance and support to the Campaign
- Confirms all recognitions and Campaign elements

2022 Recognitions

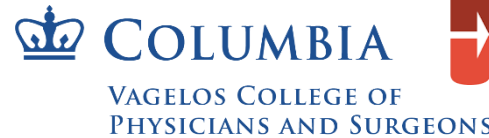
Recognition Category	# of Recognitions
Advanced Use of Sensors and Controls	11
Integrated Controls for Plug Loads	0
Integrated Controls for HVAC	2
Other Integrated Systems	2
Integrated Lighting and Horticultural Controls	2
Innovative Maintenance, Operation, and Financing Service Models	1
Exemplary Supporter	2
Diversity, Equity, and Inclusion Champion	1



THE UNIVERSITY OF VERMONT
**AGRICULTURE &
LIFE SCIENCES**



VERTICAL
HARVEST



MISSOURI SLOPE
TAILORED CARE. INSPIRED LIVING.



2022 Recognitions

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Innovative Maintenance, Operation, and Financing Service Models	1
Exemplary Supporter	2
Diversity, Equity, and Inclusion Champion	1



Holt Public Schools: Recognized ILC Participant

- **Location:** Holt, Michigan
- **Size:** 11 schools in the District
- **Lighting System Description:**
 - LED luminaires, each with wireless communication nodes
 - Remotely mounted occupancy and daylight sensors
 - Energy reporting in 15-minute increments
 - High-end trim capability
 - Commissioned remotely



Holt Public Schools: Recognized ILC Participant

- **Project Stats:**
 - 9 schools, 5,000 students
 - HS Campus: 340,000 ft²
 - 10,000+ LED fixtures
 - 8,000+ Bluetooth communicating devices
 - 3,600+ Bluetooth devices in the Holt High School alone in a single mesh network
- **Benefits:**
 - 64% energy savings over previous fluorescent system
 - Energy monitoring allowed for top-tier utility rebates
 - Integration with the BMS creates potential to leverage additional HVAC savings and consolidation of control platforms



Q&A with Holt Public Schools

1. What were the goals of the project, how were they set, and from whom did you need to get buy-in?
2. Are there other benefits/impacts you have seen with the new lighting? Have you heard any feedback from students or staff?
3. I know performing work in schools is difficult – it all must be done outside of school hours. How did you manage that?



Q&A

Contact us at EHSC@lbl.gov



Resources

Check out our campaign site's [resource pages](#), including [lighting resources](#) all in one place.

- Case studies
- Design guides
- Performance criteria
- Measurement and verification
- ... and more!



Upcoming Funding

- [Check out this page](#) for exciting new funding opportunities.
 - America's Schools Grant Notice of Intent
 - Energy CLASS prize

Attend our [webinar on Nov 8th](#) to learn more!

Grants for Energy Improvements at Public School Facilities

Bipartisan Infrastructure Law

Bipartisan Infrastructure Law » Grants for Energy Improvements at Public School Facilities



The U.S. Department of Energy recently announced more than \$80M, the first tranche of funding in a \$500M investment, to make clean energy improvements in K-12 public schools. Funds will empower school districts to make upgrades that will lower facilities' energy costs and improve student learning environments.

Read the Renew
America's Schools Grant
Notice of Intent

Learn about this first-of-
its-kind facilities
improvement program

Learn more about the
Energy CLASS prize

Learn how this prize will
empower schools to build
capacity & make energy
improvements

Join us for our next webinar!

- November 8th at 10am PT/1pm ET. Recognition Kickoff. [Registration.](#)
- November 15th at 10am PT/1pm ET. Decarbonization. [Registration.](#)

