CONVERTING A CENTURY-OLD TOWN HALL'S LIGHTING TO USE LED TECHNOLOGY

Welcome to Croton-on-Hudson's Living LED Lighting Laboratory!

Summary

Featured in this building are 11 products that convert existing light fixtures to use Light Emitting Diodes (LED), outputting the same light but consuming about half the power of standard fluorescent lamps. Funded by a grant from NYSERDA (under its Clean Energy Communities program), this project will help municipalities and others cost-effectively reduce their utility bills and greenhouse gas (GHG) emissions. The $50,000 grant covered all equipment and installation costs, and was secured by Croton's Sustainability Committee (which also designed the project).

Ten of the options are featured in the 2nd floor main corridor (one in each numbered fixture), while the other is installed in the stairwell fixtures. Two of those options have been deployed elsewhere in the building, along with 3 types of lighting controls. In total, we expect this upgrade to reduce:

- annual electric consumption by about 76,000 kilowatt-hours (kWh), worth about $12,000 per year

- peak demand by 16.4 kilowatts (kW)

- net annual GHG emissions by 16.3 short tons.

The 3 lighting controls are in:

- the basement community room where a ceiling-mounted wireless motion sensor shuts off a portion of its lighting
- the adjacent pantry where a dual-technology motion sensor wall switch shuts off all its fixtures
- stairwell LED fixtures that automatically dim (but do not go off) when no movement is sensed.

Feel free to visit those publicly-accessible spaces without an appointment, but please respect activities that may be underway in the community room and pantry.

Extra copies of this document are free to visitors at the Village Manager's office on the 2nd floor in room 24. For further information, please contact (Mr.) Lindsay Audin, chair of Croton's Sustainability Committee at info@sustain-croton.org.

Background

The Stanley H. Kellerhouse Municipal Building formerly a public school) was built in 1909. It houses our village offices, police station, court and meeting rooms, historical society, and other functions. All were previously illuminated by 3-lamp 2x4 recessed troffers with deep cell parabolic louvers containing 32-watt T8 fluorescent lamps powered by instant-start electronic ballasts. Each fixture consumed about 90 watts. After retrofit, most use about half as much power.

Wide variations in price, installation time, light output, lifetime, wattage, and other factors have challenged some personnel when choosing which LED products to purchase and use. To help overcome that problem, Croton's Municipal Building demonstrates a range of available choices.

Characteristics Of LED Light Sources

All of the following attributes may be found in one or more of the installed units. See the spreadsheet for specs on each.

TLEDs (i.e., tubular LEDs) are lamps (not "tubes" or "fixtures") that fit into fluorescent lampholders (a/k/a sockets or "tombstones") in existing light fixtures. They differ in how they are "driven" (i.e., powered). Underwriters Laboratories (UL) defines 3 types:

- Type A (found in #4 and #5 fixtures) is powered by existing electronic ballasts. Ballast compatibility was based on data provided by TLED vendors. The Type A unit in #5 (by ELB) also works with magnetic ballasts. Since no re-wiring is required, Type A units entail little installation labor, and may be cheaper than other TLEDs. Ballast compatibility and eventual failure are, however, potential issues.

- Type B (found in #1, #3, and #6) runs on line voltage through re-routed wiring connected directly to the lampholders, bypassing existing ballasts (which may be removed or remain in fixtures). Ballast compatibility and failure issues are avoided.

- Type C (found in #7) is powered by one or more LED drivers (wired directly to lampholders) purchased with the lamps. Existing ballasts are bypassed or removed, avoiding ballast issues. Type C units may provide more light with the same or fewer watts.

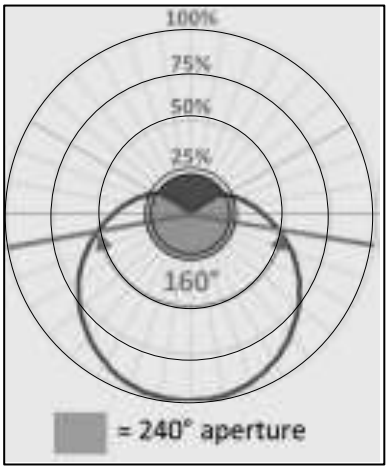
-Type A/B (found in #2) will work in either A or B mode. Fixture #2 is wired in B mode.

- Type A/C will work in A mode, or in C mode with LED drivers from the manufacturer supplying the A/C TLEDs. No type A/C units were tested.

- TLEDs are commonly powered from both ends (like a fluorescent lamp) but some are single-ended, as is the case in #3.

Retrofit kits (found in #8, #9, and #10) contain LEDs and drivers, and do not use lampholders or ballasts. They fit into, but do not replace, existing light fixtures.

Beam angle describes the included angle below a horizontal lamp wherein beam intensity is 50% or more of its maximum candela intensity (see chart at right). If much less than 150 degrees (e.g. #1, #2, #3), light levels between fixtures, on walls, or nearby vertical surfaces may be noticeably lower than with fluorescent lamps, which emit light around their 360-degree circumference. Some TLEDs have beam angles exceeding 150 degrees (e.g., #4). Aperture (also called beam spread) is the angle through which all light is emitted.



Color Rendering Index (CRI) of most TLEDs is $\geq$ 80. All our tested options are between 80 and 90.

Correlated Color Temperature (CCT) of 4000 K was chosen to match the existing T8 lamps.

L70 is the number of hours until LED output drops to 70%. L70 for all 11 options is at least 50,000 hours (~15 work years). Fluorescent lifetime (e.g., 20,000 hours) is set at the point when 50% of fluorescent lamps have failed.

Lumen output was chosen to yield the same approximate nadir foot-candle levels as T8 lamps (i.e., the point directly below a horizontal lamp).

Total Harmonic Distortion (THD) of most TLEDs is 20% or less, as are all our tested options.

Flicker % is the variation in light intensity due to alternating current cycling. Fluorescent lamps powered by magnetic ballasts flicker at 120 Hz. In a small part of the population, that may cause headaches and (in some children) behavioral problems. We found excessive flicker in 3 Type B TLEDs and in one retrofit kit. We exchanged 2 types of TLEDs and the kit's driver with units having low flicker (10% or less). Flickering TLEDs in fixture #6 were maintained to demonstrate the flicker issue.

Installed LED Options

In the 2nd floor main corridor, 7 types of TLED lamps and 3 types of retrofit kits were installed. Each has a number keyed to entries in this document's spreadsheet (page 7). LED dimming fixtures were installed in the stairwells. For vendor data, use the links on the last page of this document.

While not designed as a rigorous equipment test, various data were collected to compare the options against each other, and against existing fixtures that were not altered. Those measurements (see the spreadsheet, page 7) include: time to install, equipment cost, weight, nadir foot-candles, and flicker level.

Other data (e.g., beam spread, CRI, CCT, L70, lumen output, THD) were catalogued from vendor literature and/or DesignLights Consortium (DLC) certifications.

For the building's other spaces, Village staff chose 2 of the retrofit options, based on appearance, light distribution, project cost and funding, and ease of installation and maintenance:

- Flat plate retrofit kits by Litetronics (option #10) were installed in rooms that are routinely occupied (e.g. offices, meeting rooms), covering about 70% of the building's floor area.

- Elsewhere (e.g., basement corridors, locker / storage / rest rooms), low flicker Energy Focus Type A/B TLEDs (option #2, in A mode) directly replaced existing T8 fluorescent lamps. As those fixtures' ballasts fail over time, they will be bypassed, switching the TLEDs to their B mode.

To demonstrate lighting control technologies, 3 types were installed:

- In the basement community room (which also serves as an entrance), a wireless EnOcean occupancy sensor powered by ambient lighting shuts off most of the fixtures when the space is unoccupied. It transmits control signals to a receiver in the far left switch in the 4-gang plate next to the exit into the hallway.

- In the pantry adjacent to the community room, a dual technology (infrared plus ultrasonic) occupancy sensor by Leviton replaced the existing wall switch.

- In stairwells, Lamar OccuSmart bi-level LED fixtures dim (but never shut off) lighting. They remain dimmed until built-in sensors restore full output when they sense motion.

Lessons Learned for LED Lighting Conversions

Focus on the bottom line:

- Each of the tested options performed reasonably well. In the end, product cost and installation labor cost (due mainly to re-wiring time) most influenced life cycle costs and simple payback periods, rather than differences in energy efficiency.

- If choosing solely on economics, Type A/B units may provide the best results. While energy savings in A mode may be slightly lower than other options, units may be quickly installed without re-wiring, and never require re-ballasting. Energy savings may increase slightly as ballasts fail and the A/B units are then used in B mode.

To maximize savings, spot check present foot-candle (f-c) levels before choosing a product. If higher than needed for existing tasks, approximate the lumen output needed from the LED upgrade to achieve, e.g., 30-50 in work areas, and 15-20 in corridors. Levels may, for example, be adjusted by installing 2 high lumen TLEDs where 3 fluorescent lamps previously existed. Test the adjusted level in an occupied work space. Ask occupants to try it for a full week. If acceptable, ask others to verify it will be OK for them before changing light levels in their spaces.

- If the budget will allow, consider retrofit kits for troffer fixtures, instead of TLEDs. Ballast and lampholder issues are avoided, lifetime and L70 may be longer (though none have been installed long enough to prove it), and fixtures get a fresh new look.

Assess equipment conditions before choosing products:

Examine existing fixture ballasts and sockets. Some Type A TLEDs won't work properly with some types of ballasts (e.g., magnetic, programmed start, dimming, emergency). Verify that existing ballasts are on the compatibility list for the TLED being considered. Some TLEDs won't work with shunted sockets (i.e., contacts are internally shorted by a wire or copper strip). If sockets are found to be cracked or damaged, they should be replaced as part of the project.

If an existing fixture has been delamped (i.e., one or more lamps have been removed while others remain) and you wish to keep it that way, use Type B or C TLEDs (or Type A/B in B mode) to bypass existing ballasts. Otherwise, a ballast designed to power more lamps may send inrush current sufficient to shorten the lifetime of some Type A TLEDs.

If considering dimmable stairwell fixtures, measure existing f-c levels. If 10 f-c or less at 30" above steps, dimming much further may create an unacceptable condition.

Test before you invest:

Before choosing an option that involves re-wiring, dismantle an existing fixture on a work table to assess the difficulty (and labor time), adhering to the product's downloadable wiring diagram. If that work takes over 10 minutes per fixture, do it twice more to see if learning shortens the time.

Do not rely on vendor literature promising results "equivalent" to existing fluorescents. To see if beam spread and foot-candle levels with a desired product are acceptable, set up a test room where retrofitted fixtures are spaced the same as elsewhere in the building. Use a light meter to check for large (30% or more) foot-candle variations between and directly below fixtures at task height. If so, try TLEDs with wider beam spreads and/or higher lumen output. Such variations may not be an issue in corridors, stairwells, and small rooms.

Unless a TLED or kit specifies flicker % (preferably 10% or less at 120 Hz), check a sample using a flicker wheel or ballast discriminator to see if it emits detectable 120 Hz flicker. To ensure low flicker, specify compliance with IEEE Standard 1789-2015, "Recommended Practice 1 for Low-Risk Level". This translates to about 10% (or less) flicker at 120 Hz.

Installation issues:

Never hot swap a TLED. Doing so could damage it. Cut power to the fixture before retrofitting.

To minimize initial installation labor and avoid future re-ballasting, use Type A/B TLEDs. They may be quickly installed in A mode, and later be switched to B mode as ballasts fail over time.

To save labor time when installing dimmable stairwell fixtures, set the fixtures' controls for dimming level and cycle time *before* installation.

Plan ahead:

What you install today may be in use for 15+ years. In the future, you may want dimming capability, e.g., for demand response, or for daylight compensation in perimeter spaces. Some TLEDs and retrofit kits are dimmable, so consider that option in your purchasing specs.

1	**Fixture number**	0	1	2A	2B	3	4	5	6	7	8	9	10
2	**Brand name**	control	ThinkLite	Energy Focus	Energy Focus	Toggled	Philips	ELB	Espen	GE	RedBird	Cree	Litetronics
3	**Model No.**	std. 32W T8	TL-T8X120-10W-C-41K-G-W-N [low flicker]	Intellitube LEDFLT8-840-413-IT3F	Intellitube LEDFLT8-840-413-IT3F	A416-40210	9290011241D / 9290011241C	LEDT8-17-840-B-FHF	L48T8/840/14G-ID	LED15T8/4/840 + LED15T8/DR/UN/2L driver	S4-3-28W-41K	ZR24RK-50L-40K	RP39UQT440DLP
4	**Option Type**	N/A	type B	type B	type A	type B	type A	type A	type B	type C	retrofit kit	retrofit kit	retrofit kit
5	**lamp beam angle/spread**	N/A	120/270	120/270	120/270	105/?	220/300	115/220	120/325	120/320	180/180	118/180	110/180
6	**wired ends**	double	double	single	double	single	double	double	single	double	none	none	none
7	**install time (either lamps or kit) min:sec**	2:00	16:11	30:00	2:00	35:39	2:12	1:43	31:50	37:02	34:48	11:42	10:13
8	**nadir FC**	29.5	26.1	27.0	27.0	38.2	27.4	29.2	33.1	32.2	24.6	39.4	32.7
9	**retail matl. cost per lamp or kit**	$1.50	$37.00	$16.00	$16.00	$13.00	$10.95	$13.79	$8.88	14.95/lamp + 2 drivers @ 12.01 each	$106.69	$120.00	$84.75
10	**lamps/fixture @ 48K hrs**	9	3	3	3	3	3	3	3	3	0	0	0
11	**ballasts @ 48Khrs**	1	0	0	0	0	1	1	0	0	0	0	0
12	**total watts**	90	42	39	39	48	42	50.4	42	39	36	40	39
13	**annual energy saving @ $.16/kWh**	$0.00	$23.04	$24.48	$24.48	$20.16	$23.04	$19.01	$23.04	$24.48	$25.92	$24.00	$24.48
14	**annual tons CO2 saving @ .5 ton/MWh**	0.000	0.072	0.077	0.077	0.063	0.072	0.059	0.072	0.077	0.081	0.075	0.077
15	**ballast discriminator G=green R=red**	G	G	G		G	G	G	R	none	G	G	none
16	**flicker %**	2	2	0	2	25	2	6	35	2	2	10	0
17	**flicker freq. range Hz**	13K-17K	610-1.3K	0	17.1K-20.4K	1.1K-1.7K	1.4K-2.9K	26K-28K	305-366	0	10.3K-12.7K	88.7K	0
18	**startup speed**	instant	slight delay	instant	instant	slight delay	instant	instant	instant	instant	slight delay	slight delay	instant

Croton-on-Hudson greatly appreciates the financial and administrative assistance provided by NYSERDA and its personnel, without whom this project would not have been possible.

For further information:

- DesignLights Consortium (certifies LED device characteristics): www.designlights.org
- LED Lighting Facts: https://lightingfacts.com/
- Two comprehensive LED articles for facility managers:

https://www.facilitiesnet.com/lighting/article/How-To-Choose-the-Right-LEDs-for-Lighting-Retrofits--17429

https://www.facilitiesnet.com/lighting/article/Understand-The-ABCs-of-LED-Retrofit-Kits---17757

- Two excellent technical studies of beam spreads and other characteristics of TLED retrofits:

https://www1.eere.energy.gov/buildings/publications/pdfs/ssl/caliper_21-2_t8.pdf

https://cltc.ucdavis.edu/sites/default/files/files/publication/TLED%20Benchmark%20Report%20-%20Final%202017-11-1.pdf

The 13 suppliers whose products were used (no endorsement is implied):

#1 - Thinklite: https://www.thinklite.com/

#2 - Energy Focus: https://www.energyfocus.com/

#3 - Toggled: https://toggled.com/

#4 - Philips: https://www.usa.philips.com/c-m-li/led-light-bulbs

#5 - ELB Electronics: https://elbelectronics.com/

#6 - Espen Technologies: http://espentech.com/

#7 - General Electric (a/k/a Current): https://products.currentbyge.com/led-tubes

#8 - RedBird: http://www.redbirdled.com/

#9 - Cree: http://creebulb.com/bulbfinder/

#10 - Litetronics: https://www.litetronics.com/

Lamar: https://www.lamarlighting.com/category/occu-smart-motion-sensor-controlled-lightingVOL

EnOcean: www.easyfit-solutions.com/

Leviton: http://www.leviton.com/en/search-results#q=Ossmt-ID&t=Products&sort=relevancy&layout=card