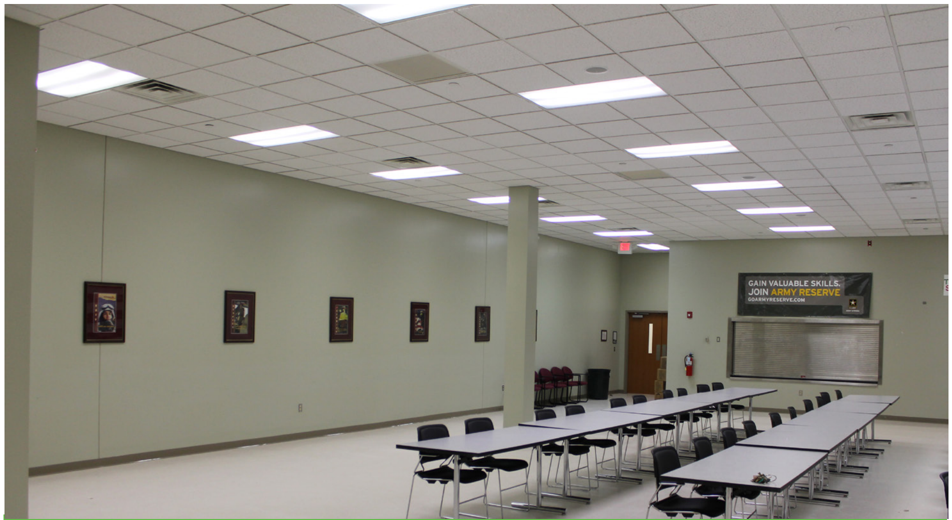
U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY



Fort Devens Army Reserve Center troffer retrofit.
Photo credit Pacific Northwest National Laboratory.

UFC 3-530-01 Highlights

Unified Facilities Criteria (UFC) 3-530-01, *Interior and Exterior Lighting Systems and Controls*, covers most lighting applications at U.S. Department of Defense facilities. UFC 3-530-01 applies to new construction, major renovations, and space redesign. This fact sheet highlights key elements of the criteria focused on interior lighting and supplements information for clarity contained in some sections.

Priorities for Lighting Systems

Section 2-1, *Priorities for Lighting Systems*, states interior lighting systems should be designed to reduce energy consumption, reduce maintenance, and improve lighting quality (often through lighting redesigns) at the lowest life-cycle cost. Section 2-1.5 states that light-emitting diode (LED) efficiencies are surpassing fluorescent efficiencies and should be considered for all interior applications.

Energy Reduction

Section 2-1.1, *Energy Reduction,* states energy consumption can be reduced by using energy-efficient technologies and effective illuminance levels and implementing control strategies. Section 4-1.1, *Energy Reduction*, acknowledges that LED fixtures are more efficient than most high-intensity discharge (HID) fixtures. LED and induction technology have proven energy savings, which is the first consideration for all exterior applications. Typical fluorescent and HID fixture efficacy is 55 to 75 lumens per watt (lm/W). There is no explicit efficacy requirement for LED fixtures in the UFC, but many on the market exceed 100 lm/W. Most LED luminaires and conversion kits are twice as efficient as fluorescent systems. LED fixtures are at least 1.5 times more efficient than HID fixtures.

Maintenance Reduction

Section 2.1.2, *Maintenance Reduction*, states maintenance can be reduced by selecting light sources, power supplies, and controls that are rated for long useful lives; by minimizing the number of luminaires on a project; and by implementing controls strategies.

LED light sources reduce maintenance costs because of their long lifespan. They can last five to ten times as long as HID lamps and three to five times as long as fluorescent lamps. UFC does not have an explicit requirement for new LED fixtures, but many LED fixtures on the market have L70 values in the 60,000 to 80,000 range. L70 is the amount of time the LED device is expected to produce at least 70% of the initial output.

Redesign Space Evaluation

- Is the space over or under lighted?
- Do the existing light fixtures need to be repaired or replaced?
- Is there significant glare in the existing lighting system?
- If new fixtures are installed, could the number of fixtures be reduced and yield better lighting conditions?

Alterations and Redesign

Section 2-8, *Lighting System Alterations*, offers designers three options when considering upgrading interior lighting to LEDs: 2-8.2 *Redesign*, 2-8.3 *Luminaire Replacement and Conversion,* and 2-8.4 *Light Source Retrofit*. These options are repeated for exterior lighting in Section 4-7, *Replacing Existing Systems*. All three of these options and lighting controls help to reduce energy usage and maintenance costs.

Sections 2-8, *Lighting System Alterations*, and 4-7.1, *Redesign*, discuss redesigns as a way "to maximize long-term energy …savings and to improve the lighting quality in existing spaces."

In a redesign, the number, type, and placement of fixtures can be changed to address new lighting recommendations for spaces. The fixture count can be reduced through the use of more efficient equipment, designing for proper light levels, and optimizing the lighting distribution.

Many existing spaces are over lighted because tasks that used to be completed on paper are now done on computers with luminous screens so less overall lighting is needed. Designers should light the task area first, then the ambient areas can often be lighted to lower levels. Optimizing the equipment saves on both energy and equipment costs.

Section 2-8 notes designers should consider a redesign before luminaire replacement, conversion, or retrofit, and the redesign should consider including controls, which offer the opportunity to optimize efficiency and lighting performance to meet current occupant needs and provide long-term energy savings. All lighting system alterations must be supported by a life-cycle cost analysis (LCCA) in accordance with UFC 1-200-02 (per Section 2-8).

Chapter 3, *Interior Applications*, provides design scenarios for most kinds of interior space (corridors, meeting rooms, offices, etc.) and includes informative sketches that show fixture types and placement as well as tables of equipment types and performance specifications including controls recommendations for each space type. Chapter 5 provides similar information for exterior lighting uses.

A redesign offers the opportunity to improve lighting quality by reducing glare and specifying appropriate illuminance levels for the space. See Appendix B, *Best Practices: Interior*, for more on these and other ways to improve lighting performance.

Lighting Controls

Lighting controls save energy and should be paired with equipment that can utilize controls when possible. All three lighting retrofit options (redesign, replace fixtures, retrofit fixtures) offer the opportunity to introduce lighting controls, if controls are not already in place. Controls can help reduce energy use and increase occupant comfort. Table 1 shows energy savings for lighting controls in commercial buildings based on a recent review of 88 papers and case studies. Section 2-2 states that lighting control requirements must meet ANSI/ASHRAE/IES 90.1, ASHRAE 189.1, and UFC 3-530-01. Greater detail on lighting controls is provided in Appendix B, Section B-4, *Control Approaches*, of UFC 3-530-01.

Table 1. Lighting Controls in Commercial Buildings

Control Strategy	Energy Savings
Daylight Harvesting	Average savings: 24% (Range 3%–60%)
Occupancy Sensors	Average savings 28% (Range -15%–60%)
Light Level Tuning	Average personal tuning savings 31% (Range 5%–78%) Average institutional tuning savings 36% (Range 10%–62%)
Multiple Approaches	Average savings: 38% (Range 5%–78%)

Reference: Lighting Controls in Commercial Buildings. *Leukos* 2012.

Daylighting Controls

Section 2-2.1, *Daylighting Control Requirements,* states "control the electric lighting in response to daylight." Many existing facilities offer the potential for daylight harvesting, although often no one has implemented it, sometimes because the original light source (e.g., HID) could not dim or because the sensor technology was too costly or difficult to implement.

Occupancy and Vacancy Sensors

Occupancy sensors (auto on/off) and vacancy sensors (manual on/auto off) are mentioned throughout UFC 3-530-01. Section 2-2.3, *Control Strategies*, notes that you should indicate in contract documents the control strategy for each space in accordance with descriptions provided in Table 2-1 *Interior Control Strategies* in Section 2-2.3. The equipment requirements tables in Chapter 3 provide detailed interior lighting strategies and requirements for various room and space types. In normally occupied spaces, control strategies must include a means for the occupant to manually turn the lights on and off. Control strategies for exterior lighting are included in the tables in Chapter 5.

Occupancy sensors can save energy, but if they are not located properly, do not have the correct coverage, or the time out period is wrong, occupants may decide to disable them. Appendix B, Section B-4, *Control Approaches*, provides useful information about controls. In some cases automatic-on occupancy sensors can lead to more energy usage than the original installation; hence, the negative savings for occupancy sensors shown in Table 1 above.

Many new LED fixtures and conversion kits are shipped with combined daylight and occupancy sensors integral to the fixture or kit. One option is to install only the occupancy sensor. It is usually more cost effective to use controls embedded in the fixture or kit rather than to buy separate sensors that must be connected to multiple fixtures in the space.

Light Level Tuning

Tuning (also known as high-end trim, task tuning, personal tuning, institutional tuning, or light level tuning) is the adjustment of light levels to meet lighting requirements or occupant preferences. Personal tuning is where each occupant can adjust the light levels to their individual preference (e.g., one workstation is brighter than the adjacent workstation). New LED conversion kits and luminaires often contain dimming drivers, and the output can be set on site via communication from a hand-held device during the commissioning process. See Appendix B, Section B-4.3, *Light Level Tuning*, for more information.

Luminaire Conversion Kit

Section 2-8.3.1 defines a luminaire conversion kit as a system that replaces the existing luminaire components to include the ballast, lamp, reflector, wiring and the diffusers when required. Luminaire conversion kits are also known within the lighting industry as retrofit kits.

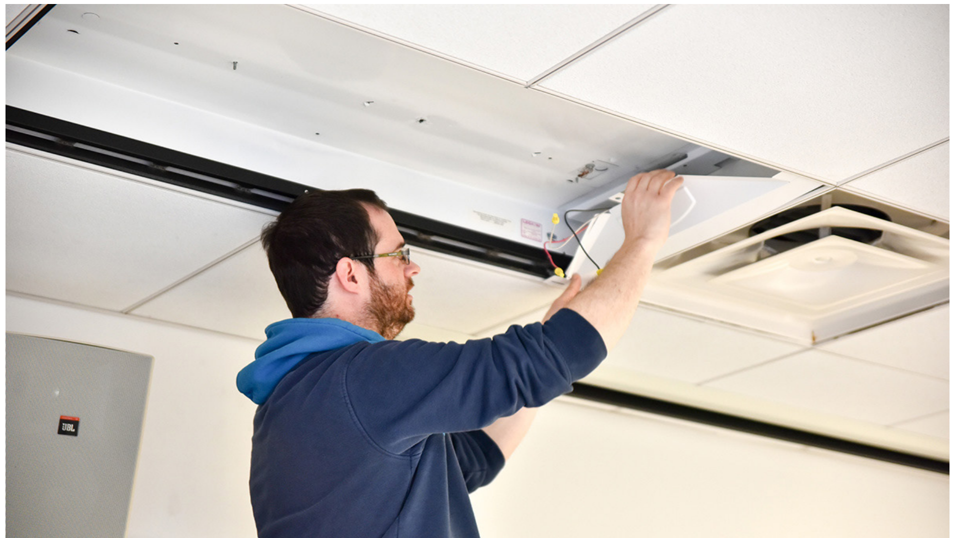
Since UFC 3-530-01 was last amended in mid-2016, LED luminaire conversion kits have become much more prevalent, with more options available and improved performance.

Some LED conversion kits are now out-performing new LED fixtures. UFC 3-530-01 only allows conversion kits for the modification of fluorescent fixtures. Direct replacement of an incandescent, fluorescent, induction, or HID lamp to an LED lamp, without any electrical or mechanical changes, is not considered to be a luminaire conversion. The section lists requirements, including a minimum efficacy of 120 lumens per watt, lumen depreciation minimum of $\geq$ L70 at 50,000 hours, and a resulting system that produces light levels equivalent to the existing system or meets the lighting levels required in the current criteria.

One challenge with conversion kits is that fixtures within a given space or on a campus could vary slightly in dimensions even if they look the same. Thus, a site assessment of fixture types is strongly recommended. This assessment needs to capture any differences in fixture dimensions or mounting methods.

Sites using conversion kits should use earthquake cables with the kit. This is a tether that is fastened to the kit and the existing fixture housing. If a seismic event happens, the cable keeps the kit from falling on people.

Section 2-1.4, *Life Cycle Cost*, requires that labor (including replacement) costs associated with equipment replacement be included in life cycle cost calculations. LED conversion kits are designed to be installed in 5 to 15 minutes.



Skilled installers can convert a troffer to a luminaire conversion kit in 10 minutes.
Photo credit Next Generation Lighting Systems, US DOE Solid-State Lighting Program.

Besides the low installation time, another key feature of LED conversion kits is that many contain dual occupancy and photo sensors. This reduces the cost of introducing controls into the space because they are integral to the retrofit kit. Lighting controls are a requirement of UFC 3-530-01.

Light Source Retrofit (TLEDs)

Tubular LED lamps, known as TLEDs, are the last option that should be considered in the retrofit process. Most TLEDs are not controls ready. TLEDs are the same shape and length as traditional fluorescent lamps, but instead of a fluorescent source, the lamps utilize LEDs. Section 2-8.4 specifically only allows UL Type A TLEDs. Type B and C TLEDs require electrical and mechanical modifications to the fixture. If modifying the fixture, a conversion kit or new luminaire is the preferred option. However, if Type A TLEDs are being considered for a site, a review of energy savings is necessary.

Types of TLEDs

- Type A - uses the existing ballast.
- Type B - existing ballast is disconnected and line voltage is supplied to the sockets.
- Type C - uses an external driver, the ballast is disconnected, and line voltage is supplied to the sockets.

Ballast Factor and Energy Savings

Ballast factor (BF) needs to be properly accounted for in determining the energy savings. Normal BF for T8 ballasts is 0.87–0.89. BF affects both light output and input power. A 32 W T8 fluorescent lamp operating on a normal BF (0.87–0.89) will draw 29–30 W. It is important to note that Type A TLEDs typically add 15–20% of the rated power to the system. This means that if the nominal wattage of the TLED is 12 W, the actual input power is 13.8–14.4 W per lamp.

Type A TLEDs often draw 15% to 20% more than their rated wattage, so a 12-W TLED may actually draw 13.8 to 14.4 watts.

Security - Physical

Lighting plays a role in physical security. Although there is no conclusive evidence that more light deters crime at night, good lighting can assist in helping secure a facility and can increase a sense of safety for occupants.

Uniformity

The human eye and cameras both adapt to the brightest area in view. Therefore, more light may not necessarily be better because the eye (and the security camera) can struggle to visually identify items in the less bright areas of the visual scene. Uniformity, the range of lighting values in an area, is mentioned in Section 2-1.3.4, *Uniformity*, Table 6-1 Minimum Lighting Criteria for Unaided Guard Visual Assessment, and throughout Section 7 *Security Lighting Applications*. The lower the uniformity ratio (e.g., 5:1, or 3:1), the less variability there is of lighting values in the measured area.

Surfaces

Light is reflected off of surfaces. Therefore, it is more important to light a wall, the fence, or the ground than it is to aim a light fixture from the top of a building into the vast expanse. Lighting into the void has limited effectiveness and more often than not creates a large glare source. Therefore, when possible, light the facades of buildings and structures rather than directing light from the facades into the open space.

Glare

Glare plays a critical role in lighting and physical security, especially exterior applications. Glare can be discomforting and if significant, can be disabling, limiting or preventing completion of a task. Glare is mentioned in Section 2-1.3, *Lighting Quality,* and throughout Chapter 6, *Security Lighting*, and Chapter 7, *Security Lighting Applications*.

The equipment requirements in Section 7 of UFC 3-530-01 often reference a G#. The # (typically 2 or less) refers to the amount of lumens (basic unit of light) emitted in the "glare" zone. The lower the G value, the fewer lumens emitted. Knowing the G value helps, but glare is dependent on the background brightness. Therefore, a fixture with a G2 value might be sufficient at an Approach Zone, but that same fixture may produce too much glare along a fence line that is on the far side of the facility where the background brightness is very low. It is important to evaluate fixtures in the context of the application, taking into account the location where the fixture will be installed.

Security - Cyber

One security area UFC 3-530-01 does not address is cyber security. New and emerging lighting and control systems typically involve some sort of intelligence or "smart" component. These new systems may be referred to as using any of the following terms: connected lighting, Internet of Things, industrial control systems, or operational technology. Although most light fixtures do not have these capabilities, they are becoming more common in control strategies.

Simple lighting controls (those that do not connect to larger systems like the internet or building automation systems) have the ability to reduce the lighting in response to daylight or occupancy, and because they do not communicate beyond the fixture/sensor combination, simple controls have virtually no cyber risks. However, some new lighting control systems utilize "the cloud" or "edge" computing to assist with additional features like asset tracking or energy management. Connected and intelligent systems increase the cyber risk in a facility.

UFC 3-530-1 Appendix A references DoD I 8500.01, *Cybersecurity*, last published in 2014. UFC 4-010-06 (2017), *Cybersecurity of Facility-Related Control Systems*, provides information about cyber security for facility-related control systems. Federal Energy Management Program (FEMP) has developed fact sheets and other resources related to facility-related control systems.

FEMP has a fact sheet related to cyber-securing facility-related control systems and is not specific to a single building system. https://www.energy.gov/sites/prod/files/2018/01/f46/cyber_securing_facilities.pdf.

FEMP also recently published a fact sheet related to cyber-securing lighting equipment specifically. https://www.energy.gov/sites/prod/files/2018/06/f52/cyber_security_lighting.pdf.

Summary

Priorities for lighting systems per UFC 3-530-01 should be designed to reduce energy consumption, reduce maintenance, and improve lighting quality at the lowest life-cycle cost.

In terms of improving lighting quality, UFC 3-530-01 prioritizes redesign, luminaire replacement and conversion, and light source retrofit in that order. UFC 3-530-01 has specific requirements for luminaire conversion kits and only fluorescent fixtures can be converted. UFC 3-530-01 only allows certain types of light source retrofits.

Lighting controls help save additional energy and include daylight dimming, occupancy sensors, and tuning. Controls are required to be considered in projects per UFC 3-530-01.

Appendices in UFC 3-530-01 offer detailed guidance on important topics such as controls, best practices, light source information, and life-cycle cost analysis. ■

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