

Interior LED Lighting Technology Navy Energy Technology Validation (Techval) Program

This demonstration project was performed by Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC) to determine the potential energy savings for Interior LED lighting technology in office environments. NAVFAC EXWC concluded that Interior LED Lighting Technology can save money in comparison to the conventional incandescent, halogen, and where cost-effective, compact fluorescent lamps.

What is the Technology?

An LED is a semiconductor-diode that emits light when power is applied. A driver is used, much as a ballast, to provide the precise current to the LEDs. LEDs are typically integrated with the luminaire and heat sink (thermal management system). LEDs are available in integrated luminaires that can be used to replace existing luminaires. LEDs are also available as direct replacement lamps for many incandescent and compact fluorescent lamps. Direct replacement LED lamps include an integrated driver and heat sink and are designed to screw into lamp sockets within conventional luminaires.

LED lamps produce light equivalent to conventional lamps (incandescent, fluorescent, induction, etc.) with less energy. LEDs consuming 6 to 8 watts, incandescent lamps consuming 60 watts, and compact fluorescent lamps (CFL) consuming 13 to 15 watts can each produce about 800 lumens of visible light.

How Does It Save Energy?

LED lighting and controls save energy in at least five ways – (1) use of energy saving high efficacy lighting fixtures; (2) use of light level sensors to maintain lighting levels automatically at a preset value; (3) use of occupancy sensors to turn off or dim lights automatically when the space is unoccupied; (4) use

of daylight sensors to automatically dim lights when



2'x4' lay-in LED luminaires

sufficient exterior light is introduced into the occupied space; and (5) dimming of the lights to meet occupant light level preference. Other types of lighting may not adapt to these controls as well as LEDs.

LEDs are more efficient at generating light (lumens) and more effective at delivering the light where it is needed (illumination). Luminaire efficiency is as important as bare lamp efficacy when maximizing overall light delivery. LEDs are a directional light source because of the way they are made. With good luminaire design, the optics of LED luminaires can be designed with minimal light going in unneeded directions, thus reducing light loss resulting from redirection (reflection). This also allows the LED luminaire to provide more uniformity of illumination. The result is less over-lighting of the area, such as immediately under the luminaire and less light being absorbed or lost within the luminaire. For this reason, LEDs frequently cannot be compared to traditional lamps using the conventional lumens-per-Watt metric. Better use of lumens, providing illumination where

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needed, and reduced light loss resulting from redirection, allows LEDs to outperform other sources with respect to illumination per applied Watt.

Where Should the Navy Apply It?

The Navy should consider LED luminaires with occupancy and lumen maintenance (lighting level) controls in new construction or in remodeling projects for which a lighting upgrade is already planned. Although pricing and efficacy are expected to improve, interior LED lighting meant to replace linear fluorescents will not generally be cost effective as a retrofit. As of 2015, LED fixtures are still not cost effective to replace tubular LEDs because the development and price of LED fixtures has not dropped enough to produce significant energy savings.

LED lighting should be considered as an alternative to any application of incandescent, halogen, and, where cost-effective, compact fluorescent lamps. Cost effectiveness is highly dependent on local utility rates, operating hours, and installed material costs, but LED performance continues to improve and costs continue to decline. While this demonstration focused on replacing the complete luminaire package (luminaire with fully integrated LED and driver), in some applications it may be possible to utilize the existing light fixture and replace the current incandescent lamp or Compact Fluorescent Lamp (CFL) with a direct replacement LED lamp.

While LEDs can perform well in dimming applications, much better than CFL technology, the application requires extreme care to ensure functionality. Dimmer switches need to be fully compatible with the LED and the LED driver. The Department of Energy (DOE) Solid State lighting (SSL) Program has issued new guidance for designers, specifiers, and LED dimming systems installers. The guidance recommends full-scale mock-ups designed to test the dimmer-LED-driver combination to validate compatibility before making large investments. This additional effort increases the early design cost but can save money in the long run (as well as frustrations in the field) when the up-front effort

identifies and resolves problems early or avoids them altogether. The technology is rapidly evolving, so even dimmers previously found to be compatible may not be compatible if the manufacturer modifies the next generation of the technology.

How Much Does It Cost and How Much Did It Save?

The cost and savings for each building are in the table on the next page. Please refer to the full reports on each project for more details on the types of lights installed in each building, the controls utilized, the existing lights, etc.

Location	Cost	# of Fixtures	kWh savings	\$savings / kWh	% savings (maintenance not included)	Simple Payback
B-373, NAVAL SHIPYARD PORTSMOUTH, ME	\$118,609	98	22,578	\$0.12	75.3%	42.8 yrs
B-330, NAVAL POSTGRADUATE SCHOOL, MONTEREY, CA	\$82,477	124	15,018	\$0.19	60.0%	28.3 yrs
B-A4, JOINT BASE PEARL HARBOR-HICKAM, HI	\$23,346	44	4,394	\$0.24	51.5%	22.4 yrs
BUILDING 656, NAVY STATION NEWPORT, RI	\$33,939	240	28,825	\$0.09	82.7%	12.0 yrs
BUILDING 1573 MCAGCC, TWENTYNINE PALMS	\$82,144	346	32,799	\$0.16	69%	8.3 yrs
BUILDING 484 NEW LONDON NAVAL STATION NEW LONDON, CT	\$10,209	223	59,463	\$0.14	82.5%	1.2 yrs
BUILDING 571A NEW LONDON NAVAL STATION NEW LONDON, CT	\$1,052	36	4,429	\$0.14	86.3%	1.7 yrs

Demonstrations that resulted in paybacks longer than 20 years exemplified good energy savings habits by facility occupants reducing the potential energy savings. Additionally, building occupancy patterns can strongly affect payback. The shortest paybacks occur in continuously lit facilities or areas of a facility with low occupancy such as stairways and corridors.

Installation costs will vary depending on the nature of the retrofit and the addition of sensors and controllers. Some installations demonstrated a longer payback period because the LED fixtures were more expensive and not much more efficient than the preexisting tubular fluorescent fixtures. Additionally, the LED lights exhibited a small increase in maintenance savings because the fluorescent lights were already relatively cheap and long lived. Therefore, it will take longer for the potential savings to accumulate. Other factors that affected the specific payback were hours of use, changes in illumination, addition or lack thereof a control system, and labor rates surrounding the installation area.

What Are the Maintenance Costs/Savings Issues?

Information on LED technologies report low maintenance and long life. The technical standard for lamp life varies based on the lighting technology. In the case of LED technology, the current standard defines lamp life as the time when lumen output has degraded to 70% of initial lumen output. The rated life of incandescent lamps and CFLs is determined when 50% of a large sample of lamps has failed.

The LED industry currently reports product life between 25,000 to 50,000 hours, or more. By comparison, typical incandescent lamps have a rated life of 1,000 hours and CFLs have a rated life around 10,000 hours. LED life is very much dependent on chip quality, heat management, and unfortunately, there is a broad range of quality for sale on the market today. LED life should be evaluated using the Illumination Engineering Societies' (IES) TM-21 manual. The TM-21 manual provides a standardized method for evaluating when an LED technology has reached its useful life. The technology is too new and evolving too fast for lamp life to be historically documented. The long life of LEDs does result in the procurement of fewer lamps, as well as the reduction in labor required

to change burned-out lamps over the life of the equipment.

The Cree luminaires installed in this study are rated for 75,000 hours of service, based on calculation methods that extrapolated test data. Cree has not specifically indicated the number of hours of test data supporting this claim, nor the extent of extrapolation. The Lithonia luminaires installed at the Portsmouth site are rated for 50,000 hours -- using data extrapolated in accordance with IES standard TM-21. The control strategy of using a photocell (daylight sensor) to provide for lumen maintenance for the LEDs ensures that lighting remains at a constant brightness over the life of the LEDs and prevents over lighting at the beginning of life or the need for manually adjusting lighting levels during the life. By not being over lit at the beginning of life, energy is saved throughout the life of the luminaire. At the end of life, however, the entire LED luminaire must be replaced.

Maintenance costs for the fluorescent fixture lamp replacements is estimated to be approximately \$40 per fixture assuming each lamp will be replaced twice during the 75,000 hour life of the LED luminaire. Maintenance cost for fluorescent fixture ballast replacements during the 75,000 hour timeframe is estimated to be approximately \$50 per luminaire assuming one group re-ballasting, a total of \$90 per fluorescent fixture. Wireless lithium cell battery-powered controls were selected to reduce the LED lighting controls installation labor for this demonstration retrofit project. The lithium cell batteries are rated for ten years of life so will need changing once during the life of the luminaires. Maintenance costs for the controller battery replacement are estimated to be approximately \$10 per fixture. Net avoided lifetime maintenance costs when using the LED luminaires is approximately \$80 per luminaire. Because of the difficulty of accurately pricing avoided maintenance, this estimate has NOT been factored into the simple payback calculations but, if accurate, would reduce the simple payback by approximately three years for each of the sites.

While LED technologies offer long lamp life, particularly in comparison to incandescent technologies, it is important to remember that luminaire maintenance (done to reduce light loss factors) is still important to maintain light output and proper illumination.

LEDs have the potential to reduce energy consumption and save maintenance costs. The demonstration confirmed the energy savings for the LED fixtures and lamps. Due to the time constraints of this demonstration, the maintenance cost savings were not validated.

What Are the Findings, Conclusions, and Recommendations?

Findings

NAVFAC EXWC determined through this project that LED lighting systems can cost effectively save energy. The installations at different locations showed percentage savings ranging from 51.5% to 86.3% with simple pay backs from 42.8 years to 1.2 years. These ranges vary because of the comparative initial installation cost.

Conclusions

LED lighting should be installed with controls that maintain lumen levels throughout the life of the lamp. The advantages of LED technology in indoor lighting applications are:

- LEDs provide a longer lamp life (expectations of 25,000 to 50,000 hours). The technology, however, is too new for true lamp life to be validated.
 - An 80% reduction in power and energy (compared to incandescent) is possible, while maintaining or improving illumination levels.
 - LEDs are more durable than other lighting technologies, resulting in less lamp breakage.
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The disadvantages of LED technology in indoor lighting applications are:

- LED equipment costs more than conventional incandescent or compact fluorescent.
- Dimming control circuits that combine different lamp-driver types can be problematic.
- Because of the longer lamp life, lumen depreciation will be the reason to change lamps rather than lamp burn out. This is a change in operations and maintenance practice.

Cost projections predict that similar projects with only lamp replacement could have a simple payback in as little as 0.4 years when not taking into account savings due to a reduction in maintenance and slightly better at 0.3 years when maintenance is taken into account. Light fixture replacement could have a simple payback of 20 years when maintenance is not included and as little as 7.1 years when maintenance is included.

LED lighting for interior applications is now a high quality cost effective technology in high utility rate areas. The technology continues to improve and cost continues to come down which will make this technology attractive in more and more applications. The use of occupancy sensors can save lighting energy with minimal design effort although the commissioning efforts of lighting control systems, like the Lutron EcoSystem® used on this project, can somewhat extend normal commissioning times.

Recommendations

NAVFAC EXWC recommends that candidate projects for replacement lighting include investigations to determine the needs of the occupants, measure existing lighting levels to determine if areas are over illuminated, and evaluate the cost versus the potential savings to determine the payback for the investment. Also, depending on the type of existing light fixtures, consider discrete occupancy control additions to the existing lighting circuits to provide similar energy savings for less invested costs.

On dimming control circuits, consider developing full-size mock-ups to ensure compatibility among the LED,

driver, and dimmer control. Because LEDs are more effective at delivering light, care is required to prevent over-lighting.

- LED fixtures should be considered for new construction due to the potential energy savings over conventional incandescent or fluorescent fixtures.
- Incandescent lamps should be replaced with LED lamps.
- Replace MR-16 lamps with LED lamps since this type of fixture is used to provide accent lighting and is usually on most of the time.
- Consider replacing existing CFL, high-intensity discharge (HID), or halogen lamp light fixtures/lamps with LED fixtures/lamps in hard to access locations such as stairwells and high bay applications. This will save maintenance costs and reduce exposure to hazards as well as save energy.
- Evaluate LED lights for incorporation of controls such as dimming and occupancy sensors.

User findings/comments

LED lights were installed in interior offices at multiple locations. Paul Mcdaniel was contacted about the installation at three bases: Pearl Harbor Hawaii, Naval Post Grad School California, and Navy Station Newport Rhode Island. After installation, the LED lights are performing as expected with no additional problems. There has been an overall satisfaction with the new lights with no complaints. They continue to operate well and provide sufficient light for those working in the office environments. There has been no need for maintenance and the LED lights are projected to last for twenty years. It was noted that after ten years the lithium cell batteries in the sensors will need to be changed. This complies with the projected maintenance upon installation.

Are More Studies or Demonstrations Needed?

More demonstrations are not needed to validate the recessed troffer luminaires, surface mounted stairwell luminaires, or the control strategies demonstrated in this study. However, because LED and controls technology is rapidly advancing and prices are expected to continue to fall, the economic merits of any individual project will need to be calculated using current information.

LED has proven itself to be energy efficient and cost effective as a new lighting technology. However, the state of LED technology is still evolving. Efficiency is improving and product costs are declining. Further, the DOE SSL program continues to conduct research, sponsor product testing and demonstrations, and assist in the development of new standards and guide specifications. The Navy can still benefit from sponsoring additional demonstrations on the specific LED technologies and applications of interest to the Navy. On the other hand, the technology has progressed sufficiently in some capacities and applications, where the Navy should begin to be

sufficiently comfortable with the state of the technology to build LED lighting into its current design specifications for new facilities and evaluate LED lighting for existing luminaire replacement opportunities throughout shore facilities.

Studies in more diverse environments may reveal features and obstacles that were not found in this demonstration. Testing of new and evolving LEDs and LED control technology will continue to be warranted to further validate economic advantages.

For a full report on this project go to:

https://hub.navfac.navy.mil/webcenter/portal/exwc/Business_-_Program_Lines/page16/page160/page1455?_afrLoop=45662220730323&_adf.ctrl-state=2gppxgl9i_105#!

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