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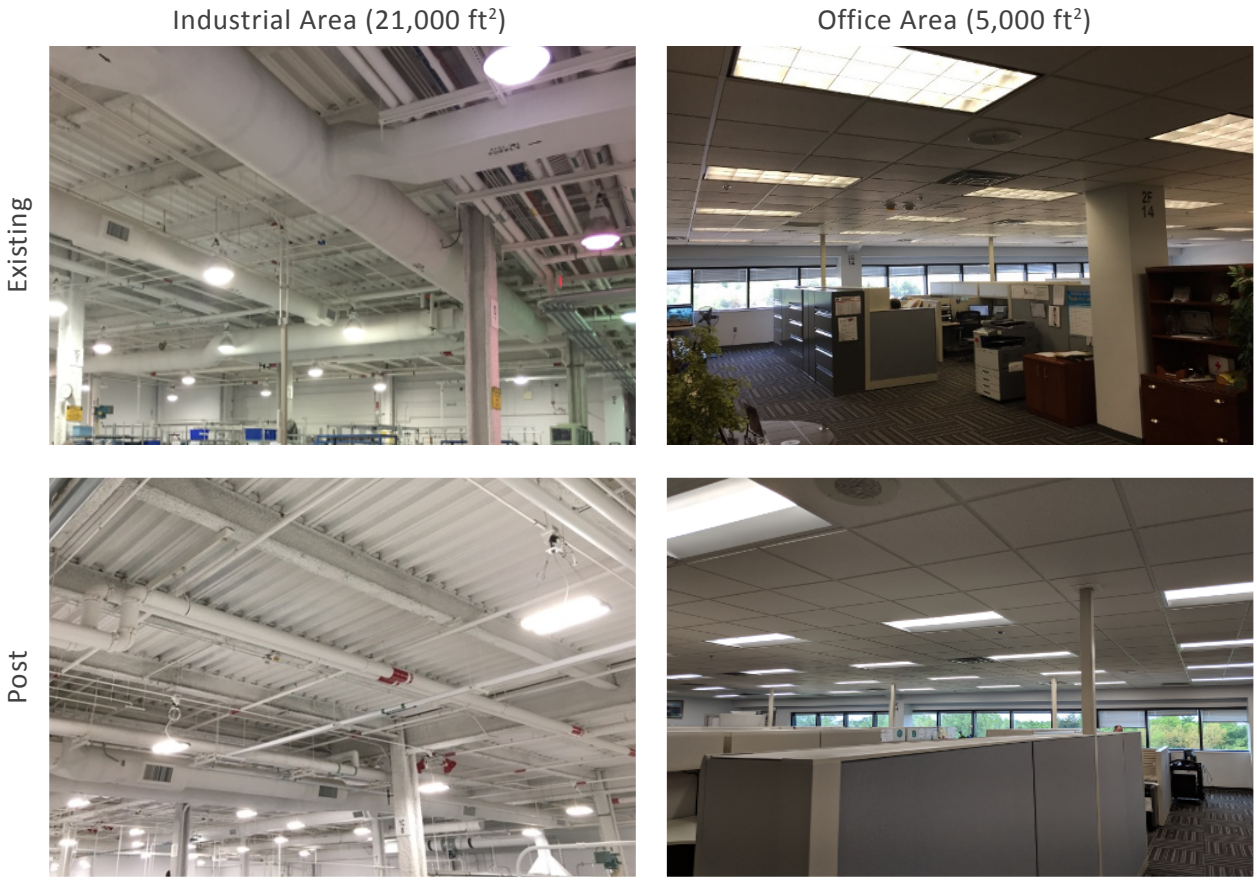
Lighting System Integration with HVAC and Plug Loads: Tinker Air Force Base

The Environmental Security Technology Certification Program is the U.S. Department of Defense's environmental technology demonstration and validation program. The program's goal is to identify and demonstrate cost-effective technologies that address the U.S. Department of Defense's highest priority environmental requirements. This document provides an overview of findings for an Environmental Security Technology Certification Program field demonstration project focused on evaluating the integration experience and resulting energy savings from integrating lighting; heating, ventilation, and air-conditioning (HVAC); and plug-load controls in an office and industrial space at Tinker Air Force Base in Oklahoma City, OK. Visit https://integratedlightingcampaign.energy.gov/ for more information about the benefits of integrating lighting systems with other building systems.



Before and after images of spaces at Tinker AFB that were retrofit with lighting integrated with other building systems as part of this study

ABOUT ESTCP

The Environmental Security Technology Certification Program (ESTCP) is the U.S. Department of Defense's environmental technology demonstration and validation program. The program's goal is to identify and assess innovative technologies that address DoD's high-priority environmental requirements efficiently and cost-effectively.

FINDINGS

LIGHTING

By replacing the existing lighting with LED fixtures, this project saved more than 60% energy compared to the existing technology. This is consistent with savings of converting either fluorescent or high-intensity discharge fixtures with either new LED fixtures or retrofit kits, which typically result in at least 45% savings. The lighting controls saved between 8-23% compared to the LED baseline. Because LEDs are very efficient, the new LED baseline uses less energy. As a result, the 20%+ savings does not result in sufficient savings for a reasonable payback. However, using lighting controls to control other building systems can make the lighting and control system more cost effective.

LIGHTING & HVAC

- Integrating lighting controls with the HVAC system led to an impressive 26% energy savings from the mechanical system on a space weighted average.
- The office space realized 12% energy savings from the mechanical system and the industrial high bay space realized 30% energy savings from the mechanical system.
- The HVAC integration was highly cost effective and reduced the simple payback of the lighting system by 39%.
- Active coordination between the electrician and mechanical teams that handled lighting and HVAC separately was critical to success.

LIGHTING & PLUG LOADS

- Integrating controlled receptacles with the lighting occupancy sensors resulted in 38% energy savings, but only 25 kWh total annual savings for the 14 receptacles.
- Achieving a cost-effective solution was a challenge, in part because the loads selected for the controlled outlets were low-power devices.
- Proactive device management with controlled plugs might have achieved greater savings, meaning an on-site person or instructions reminding staff to use the controlled receptacles and which devices can/should be plugged into them.
- When initially installed, the receptacles were not communicating with the occupancy sensors. Functional testing of the receptacles is critical, and it should not be assumed that they are communicating.
- Labor represented a large portion of cost of the controlled outlets. Firmware (software that provides low-level control for hardware) had to be updated for the receptacles to work properly.

TECHNOLOGY OVERVIEW

Lighting control sensors and additional hardware were supplied by Enlighted, the vendor. Each light fixture contained a combined occupancy/daylight sensor, and other features. Signals from the occupancy sensors in the lighting system communicated with the building automation system to adjust HVAC settings depending on the occupancy status of the space. For example, when the space became vacant, the HVAC system set back the temperature slightly and made other changes.

The signal from the occupancy sensors were also used to control a portion of the plug loads in the offices. Fourteen receptacles were replaced with “smart” receptacles that included a wireless receiver. The lighting control system sent a wireless signal indicating that the space was unoccupied and turned off the receptacles. This strategy primarily occurred during evening and weekend hours.

LIGHTING SYSTEM

The project replaced the lighting 1-for-1 in both the high bay and office spaces. Table 1 provides an overview of the lighting equipment.

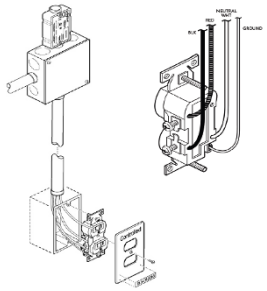
Table 1: Lighting Overview

	Industrial Area		Office Area	
Location	Baseline	New Equipment	Baseline	New Equipment
Fixture Quantity	84	84	84	84
Fixture Type	1-lamp high-intensity discharge industrial	LED Industrial	3-lamp fluorescent troffer	LED Troffer
Fixture Manufacturer		Flex LED	Troffer	Finelite
Fixture Wattage	≈ 267 W	107 W	≈ 87 W	31 W
Fixture Efficacy	≈ 63 lm/W	166 lm/W	≈ 66 lm/W	134 lm/W
Lighting Power Density	1.07 W/ft^2	0.43 W/ft^2	1.46 W/ft^2	0.53 W/ft^2
Equipment Savings	---	**60%**	---	**64%**
Energy Use	97,936 kWh	30,566 kWh	20,761 kWh	6,851 kWh
Energy Use Intensity	4.66 kWh/ft^2	1.44 kWh/ft^2	4.15 kWh/ft^2	1.37 kWh/ft^2
Lighting Control Savings	---	**23%***	---	**8%***
Total Energy Savings	---	**69%**	---	**67%**
Note: *Control savings compared to LED baseline				

Beyond new LED lighting fixtures, the new fixtures also included integral lighting controls with combined daylight and occupancy sensors.

In Table 1, the lighting control savings are applied to the new LED baseline. For both spaces, the new fixtures saved over 60%. As a result, even though the controls saved 23% in the industrial area, the total savings only resulted in 69% compared to the existing baseline.

Switched receptacle with labels



Plug-Load Controller

PLUG LOAD SYSTEM

Controlled plug loads are simple concepts. Many devices draw power when the space is unoccupied. The occupancy sensor in the light fixture can help determine if the space is empty. Connecting the outlet to the occupancy sensor can turn off the outlet when the space is unoccupied. In this field demonstration project, 14 outlets were rewired to include an outlet that was controlled in-line with a receiver that interfaced with the occupancy sensors. One of the outlets was always on and the other outlet was controlled and connected to the occupancy sensor. A majority (55%) of the plug load energy use occurred in the off hours. This was true both in the baseline and during the post-installation monitoring period. The fact that a majority of energy use is during off hours demonstrates the saving potential of this technology.

MECHANICAL SYSTEM

No new mechanical equipment was used or needed as part of this project, except for a device to allow for communication between the lighting system and the mechanical system was required. During the process of the field demonstration project, it was discovered that some mechanical equipment was not functioning as intended and, therefore, had to be fixed and maintained. It was happenstance that the evaluation required scrutiny of the mechanical system and as a result, general maintenance was required. Repairs/maintenance occurred and were excluded from the costs because they were not a function of this evaluation. The material costs (communication device between lighting and HVAC) and required labor to install the device and configure the HVAC system represent the total HVAC costs of this project.

ENERGY SAVINGS

The energy savings achieved due to the integration of HVAC, plug loads, and lighting is reported in Table 2. The total energy savings from the mechanical system was 262 MMBtu and roughly 60,000 kWh with a building energy savings of 26%. Differences in savings achieved could relate to HVAC zone size, the frequency to which the spaces were occupied compared to the assumed schedule, or other factors. The average savings across the 14 receptacles from this plug load controls strategy was 38% compared to the baseline. Although a large portion of savings was achieved, the aggregate annual energy saved was only 25 kWh, which translates into just 1.8 kWh per receptacle.

Table 2: Total Project Energy Saving

	Lighting		Mechanical		Plugs	
Location	Annual Savings	Energy Savings	Annual Savings	Energy Savings	Annual Savings	Energy Savings
Industrial area	67,370 kWh	69%	53,585 kWh 241 MMBtu	30%	---	---
Office area	13,910 kWh	67%	6,284 kWh 21 MMBtu	12%	25 kWh	38%
Combined	81,280 kWh	69%	59,850 kWh 262 MMBtu	26%	---	---

COST ANALYSIS

Table 3 presents the costs and annual savings by the building system and the various system combinations. The simple payback for each of the systems, when analyzed independently, ranges from 1.4 year to never. In practice and application it may be difficult to truly separate and treat the systems as independent.

The simple payback (SPB) for only the lighting and controls system is 12 years (using national average energy rates). Although the HVAC system adds more than $11,000 of initial cost ($7,934 estimated labor and $3,278 for integration hardware for systems to communicate), the combined SPB of lighting and HVAC is 7.3 years. The HVAC savings reduces the lighting SPB by 39%. The savings achieved by the mechanical system are operational and required little equipment. In this case, the equipment was communication related and not physical, mechanical equipment. These operational savings dramatically improve the cost-effectiveness of the combined systems.

In contrast, the introduction of the plug load controls increases the SPB of the lighting and plug loads, as well as the entire system. The plug loads added $10,029 in first costs. However, much of that added cost was because firmware in the plug controllers had to be updated, increasing the labor costs.

Table 3: Project Cost Analysis

	Lighting	Mechanical	Plugs	Lighting + HVAC	Lighting + Plugs	Total (Lighting + HVAC + Plugs)
Material	$69,145	$3,278	$2,329	$72,423	$71,474	$74,752
Labor	$33,737	$7,934	$7,700	$41,671	$41,437	$49,371
Total Cost	$102,882	$11,212	$10,029	$114,094	$112,911	$124,123
Electricity Saved (kWh)	81,280	59,850	25	141,130	81,280	141,155
Electricity Annual Savings	$8,567	$6,308	$3	$14,875	$8,570	$14,878
Gas Saved (MMBtu)	---	262	---	262	---	262
Gas Annual Savings	---	$820	---	$820	---	$820
Total Annual Savings	$8,567	$7,128	$3	$15,695	$8,570	$15,698
Simple Payback (years)	12	1.6	Never	7.3	13.2	7.9
* U.S. Energy Information Administration national average energy rates of $0.1054/kWh and $3.13/MMBtu						