Recent field experience and lessons learned related to automatic controlled receptacles

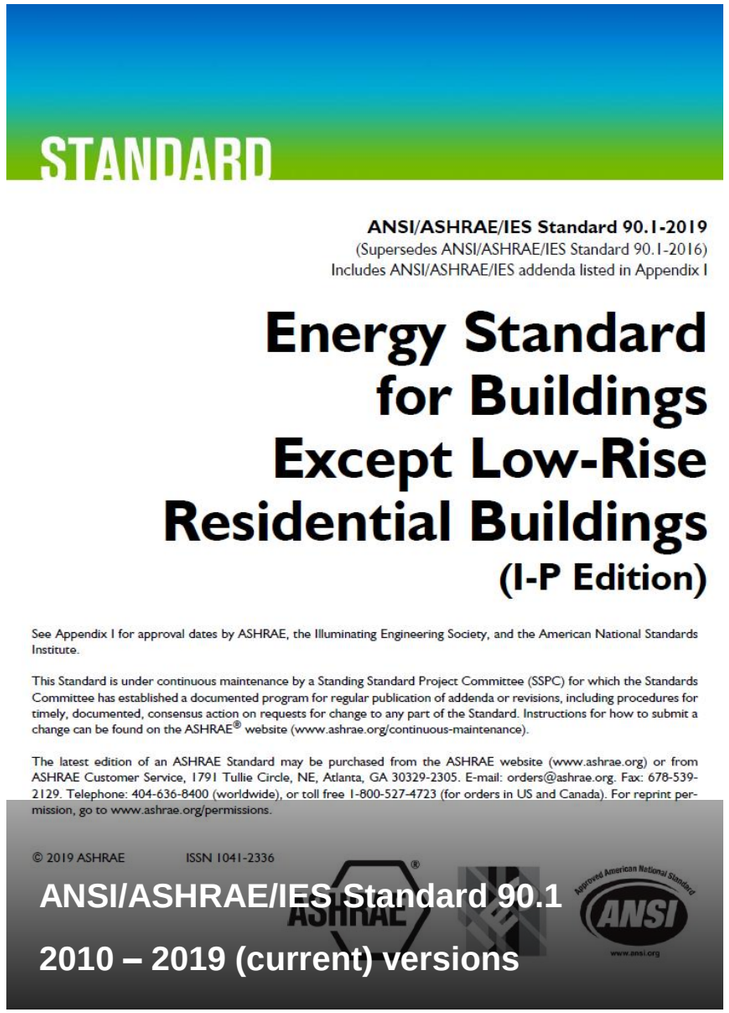
Michael Myer

Pacific Northwest National Laboratory, Senior Researcher

CalPlugs Workshop #18

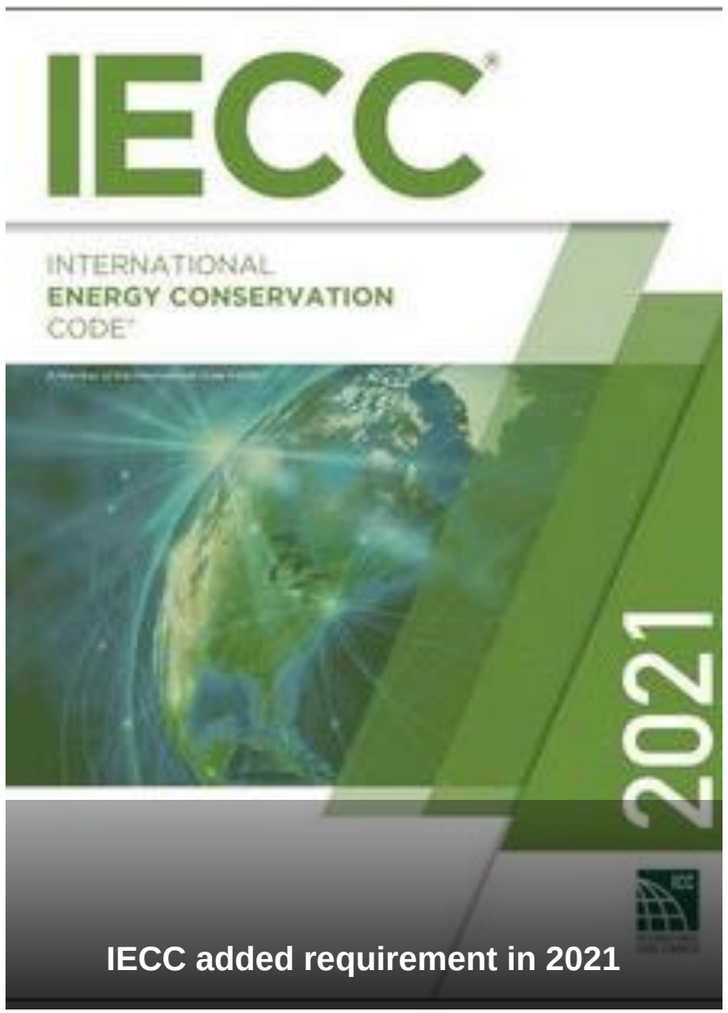
PNNL is operated by Battelle for the U.S. Department of Energy

Energy codes across the country require some form of automatic receptacle control

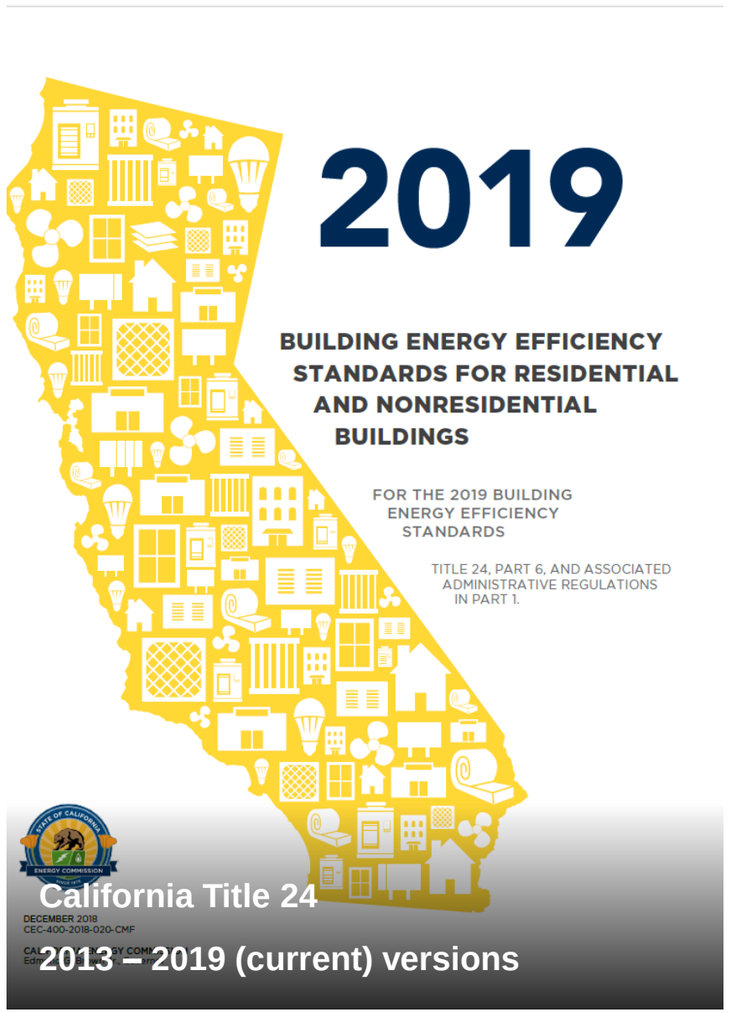


ANSI/ASHRAE/IES Standard 90.1

2010 – 2019 (current) versions



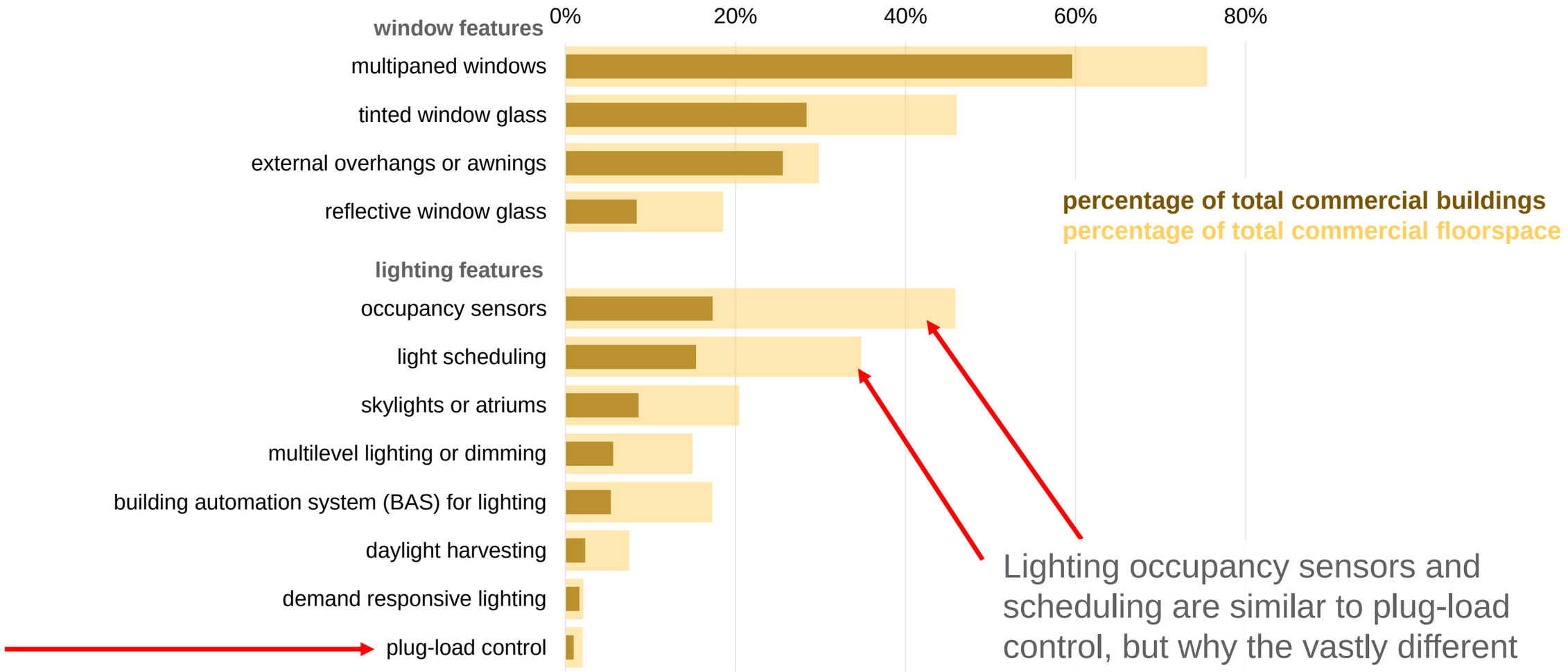
IECC added requirement in 2021



California Title 24

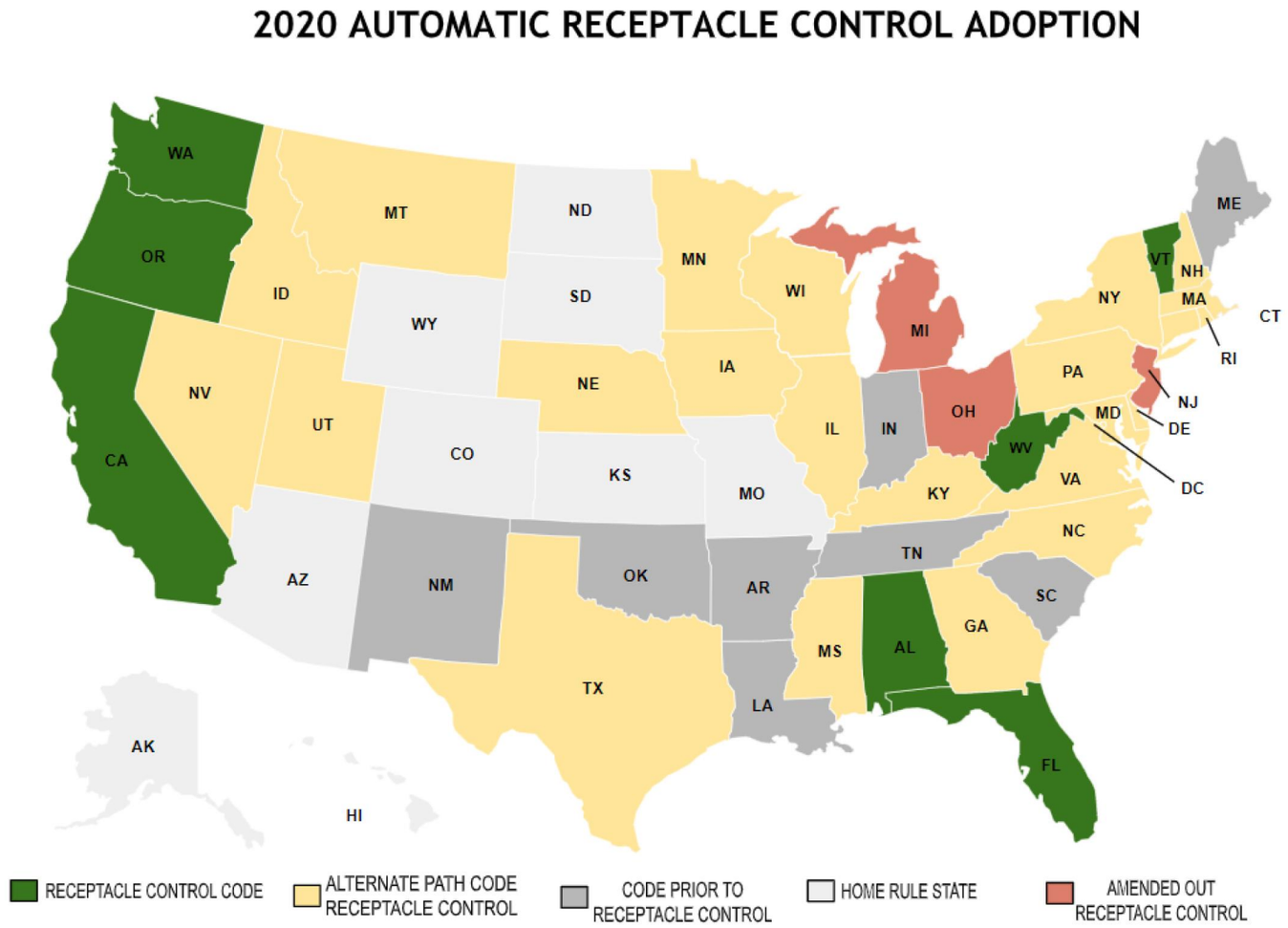
2013 – 2019 (current) versions

Despite energy code requirements - Low penetration of plug-load controls (CBECS 2018)



Lighting occupancy sensors and scheduling are similar to plug-load control, but why the vastly different level of penetration?

Despite code requirements, implementation across the country is mixed results



Source: US DOE Better Buildings Alliance Plug and Process Loads Team Webinar, Harold Jepsen – April 30, 2020

Users and space occupants pushback against code requirements for automatic receptacle controls

b. Section 8.4.2

Exceptions to 8.4.2

Receptacles for the following shall not require an *automatic control device*:

1. Receptacles specifically designated for *equipment* requiring continuous operation (24/day, 365 days/year).
2. *Spaces* where an *automatic control* would endanger the safety or security of the room or *building* occupants.
3. The building complies with one of the following:
   a. Results of performance compliance under Section 11 or Appendix G are at least 5% better than the minimum.
   b. COMcheck envelope compliance report passes by minimum of 3%.
   c. COMcheck lighting report passes by a minimum of 5%.

Oregon's energy code allows projects that are more efficient in performance, envelope, or lighting by certain values to not have meet the automatic control requirements

Other codes have entertained similar proposals

Example:
20,000 square foot office
LPD: 0.64 W/ft2 → 12,800 W (lighting power allowance)

To not use controlled receptacles, site only installs:
12,160 W of lighting

Is that a sufficient trade off compared to using controls?

Plug loads need to be managed

Pilot Study of a Plug Load Management System: Preparing for Sustainability Base

Scott Poll
Intelligent Systems Division
NASA Ames Research Center
Moffett Field, CA 94035
Email: scott.poll@nasa.gov

Christopher Teubert
NASA USRP Intern
Iowa State University
Ames, IA 50011
Email: teubert@gmail.com

***Abstract*—NASA Ames Research Center's Sustainability Base is a new 50,000 sq. ft. high-performance office building targeting a LEED Platinum rating. Plug loads are expected to account for a significant portion of overall energy consumption because building design choices resulted in greatly reduced energy demand from Heating, Ventilation, and Air Conditioning (HVAC) and lighting systems, which are typically major contributors to energy consumption in traditional buildings. This paper reports on a pilot study where data from a variety of plug loads were collected in a reference office building to understand usage patterns, to make a preliminary assessment as to the effectiveness of controlling (i.e., turning off and on) selected loads, and to evaluate the utility of the plug load management system chosen for the study. Findings indicate that choosing energy efficient equipment, ensuring that power saving functionality is operating effectively, promoting beneficial occupant energy behavior, and employing plug load controls to turn off equipment when not in use can lead to significant energy savings. These recommendations will be applied to Sustainability Base and further studies of plug load management systems and techniques to reduce plug energy consumption will be pursued.**

I. Introduction

In the past several years there has been tremendous interest in green technologies and sustainable practices within the building industry. In the United States there were approximately 130 million residential housing units in 2009 [1] and nearly 5 million commercial buildings as of 2003 [2]. In 2007, residential and commercial building construction and renovation was estimated to cost 1.2 trillion dollars, over 8% of the U.S. gross domestic product. Residential and commercial buildings accounted for 40% of total U.S. primary energy consumption and 72% of electricity consumption [3] and were responsible for 40% of carbon dioxide emissions in 2009 [4].

Several government initiatives have focused attention on sustainability, energy efficiency, and the environment. One such initiative is NASA's Renovation by Replacement (RbR), which aims to replace outdated and inefficient buildings at NASA centers with new, energy-efficient buildings. NASA Ames Research Center won a RbR competition and worked with partners to design and build Sustainability Base (depicted in Figure 1 and named to associate with Tranquility Base, the site of the first human moon landing), a 50,000 sq. ft. high-performance office building targeting a LEED Platinum rating. In addition to using commercially available technologies,

Fig. 1: NASA's Sustainability Base Building

Sustainability Base will employ innovations and technologies originally developed for aerospace missions to monitor and control building systems while reducing energy and water consumption.

A goal of Sustainability Base is to provide a research testbed where different sustainable technologies and concepts can be implemented, tested, and demonstrated. One example, and the focus of this paper, is measuring and controlling electrical plug loads. Whereas in traditional, minimally code-compliant office buildings plug loads may account for 25% or less of total energy consumption, in high efficiency buildings plug loads may account for more than 50% of the total energy consumption [5]. Since Sustainability Base was not occupied at the time of this investigation, the pilot study of a plug load management system was conducted in a traditional building with similar electrical loads. Lessons learned in this pilot study and in other studies [5]–[7] will be put to use in Sustainability Base.

II. Pilot Study

In preparation for deploying a plug load management system in Sustainability Base, a pilot study was conducted on the NASA Ames campus during the spring and summer 2011. The goals of the pilot study were to passively collect data from a variety of plug loads, to make a preliminary assessment as to the effectiveness of controlling (i.e., turning off and on) selected loads, and to evaluate the utility of the plug load management system chosen for the study.

The study was performed using a plug load management

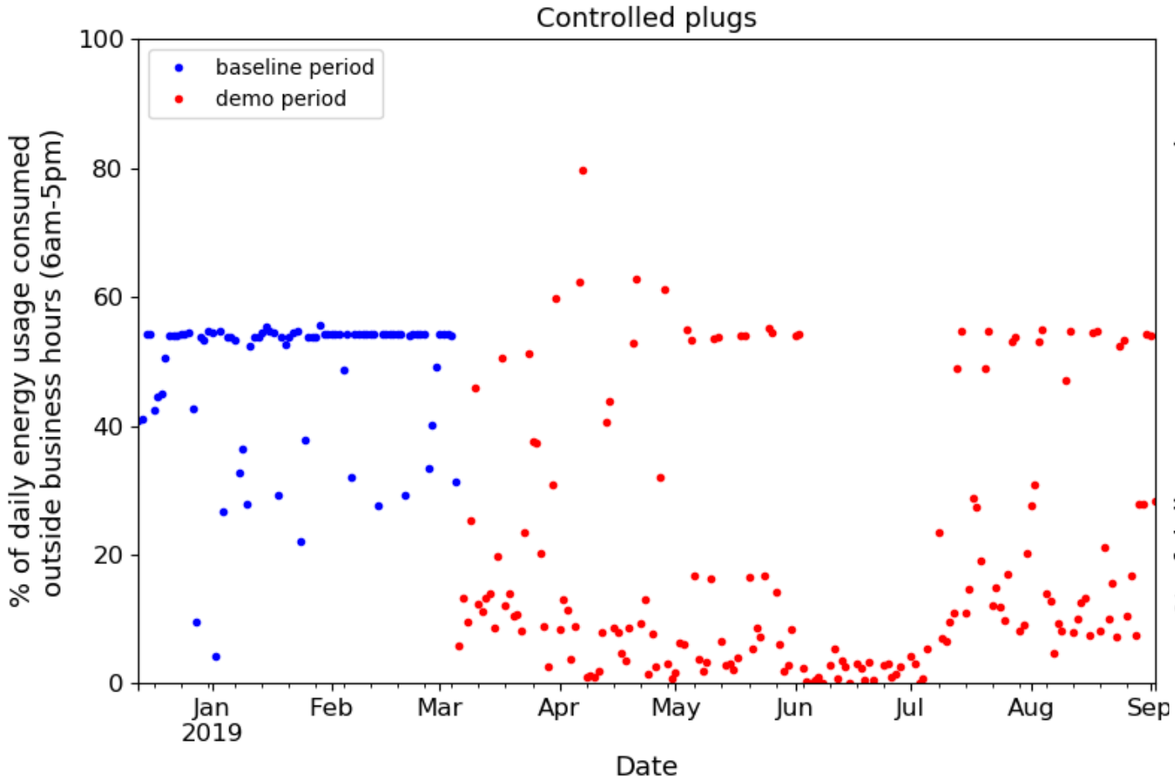
Plug loads may account up to 25% of total energy in a minimally code-compliant building.

Plug loads may account for more than 50% of total energy consumption in a high-efficiency building.

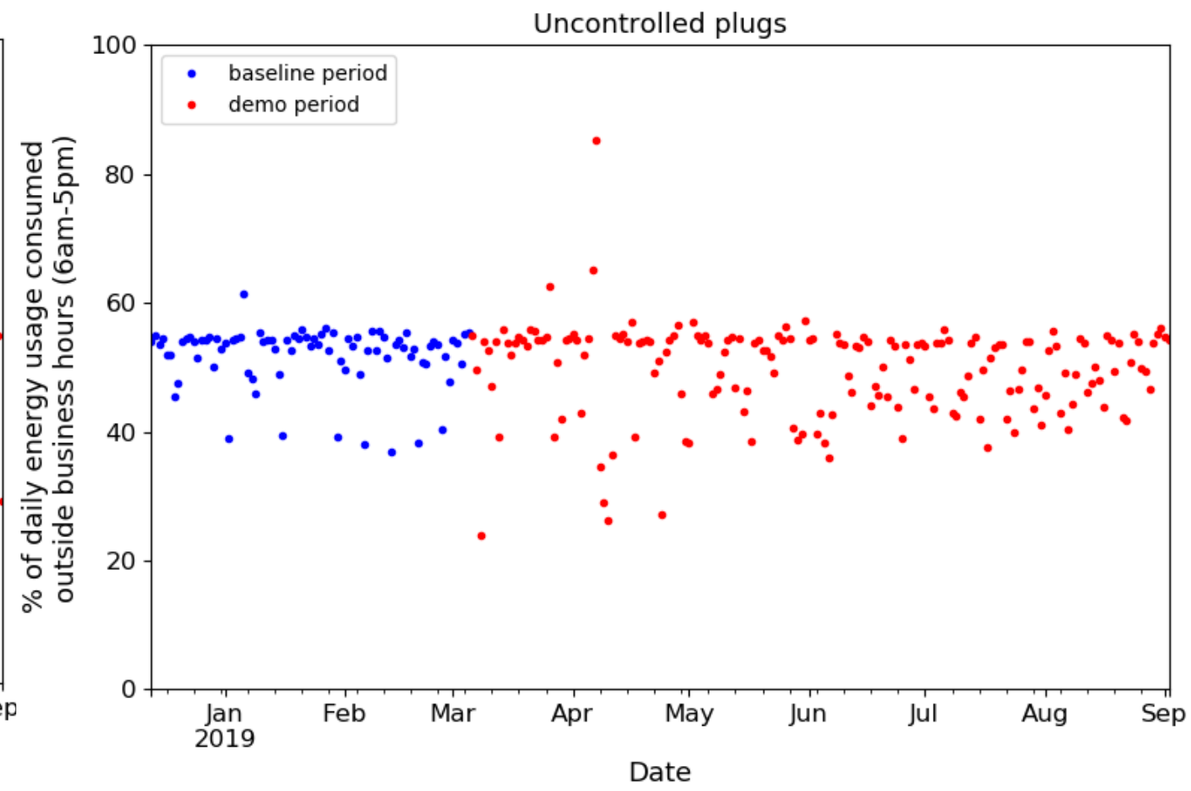
Improved plug load management could result in sizeable building-level energy savings

Automatic Plug Load Controllers turn off loads when space is unoccupied

Percentage of **controlled** plugs daily energy usage OUTSIDE normal operation hours (5:00 pm – 6:00 am)



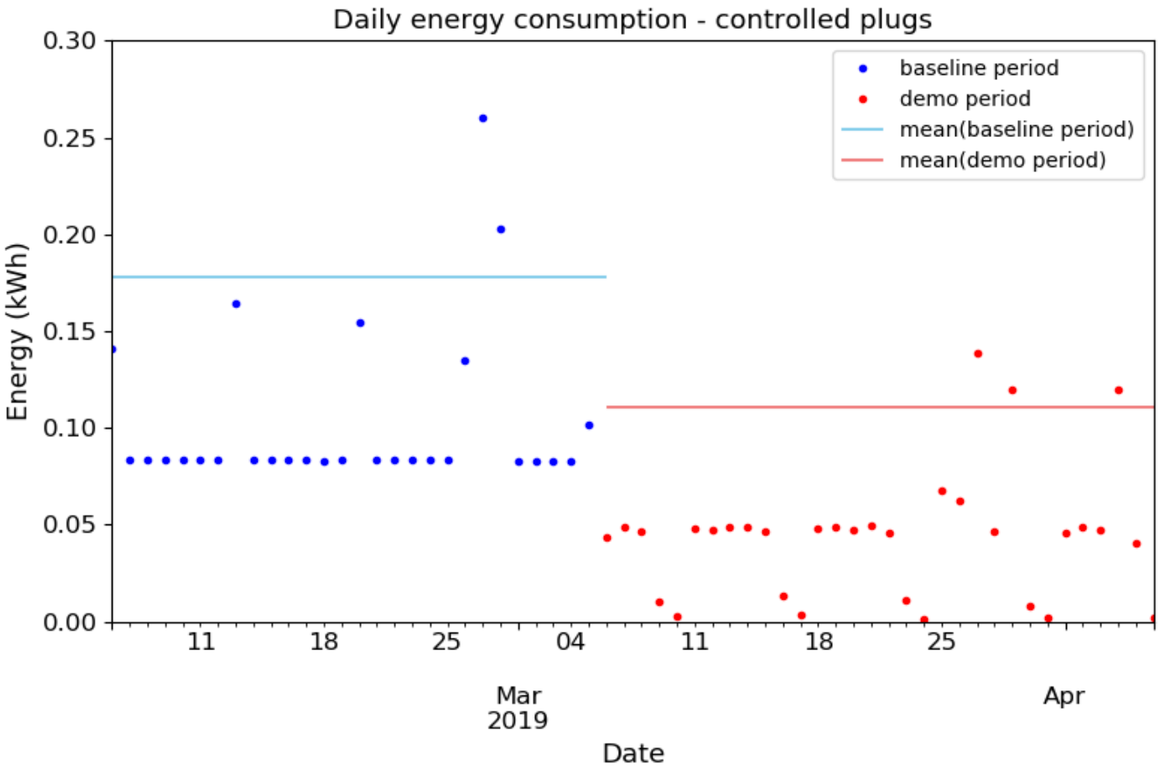
Percentage of **uncontrolled** plugs daily energy usage OUTSIDE normal operation hours (5:00 pm – 6:00 am)



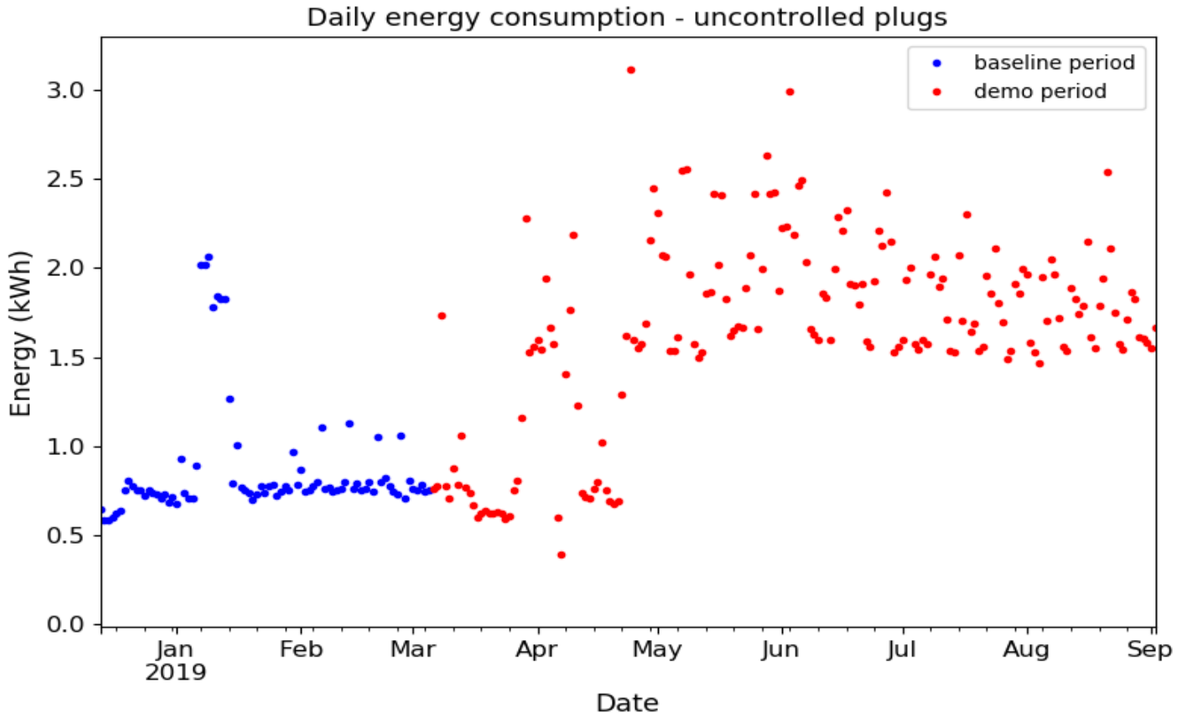
Substantial energy use of plug loads when the building was closed – need to get cost effective controls

Challenge with plug load controllers – occupants can thwart the devices

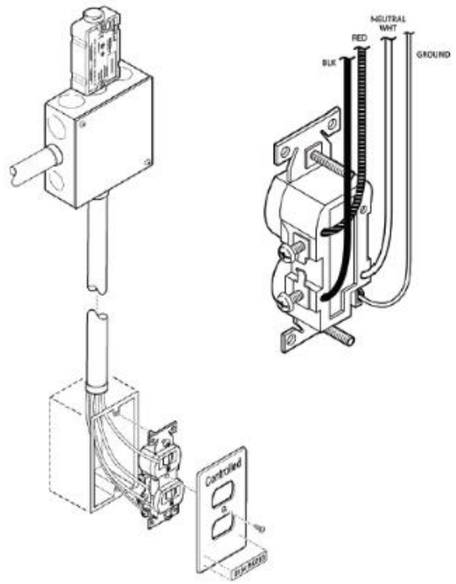
Controlled plugs mainly operated low power devices



Uncontrolled plugs operated higher power devices, during analysis, load increased as well



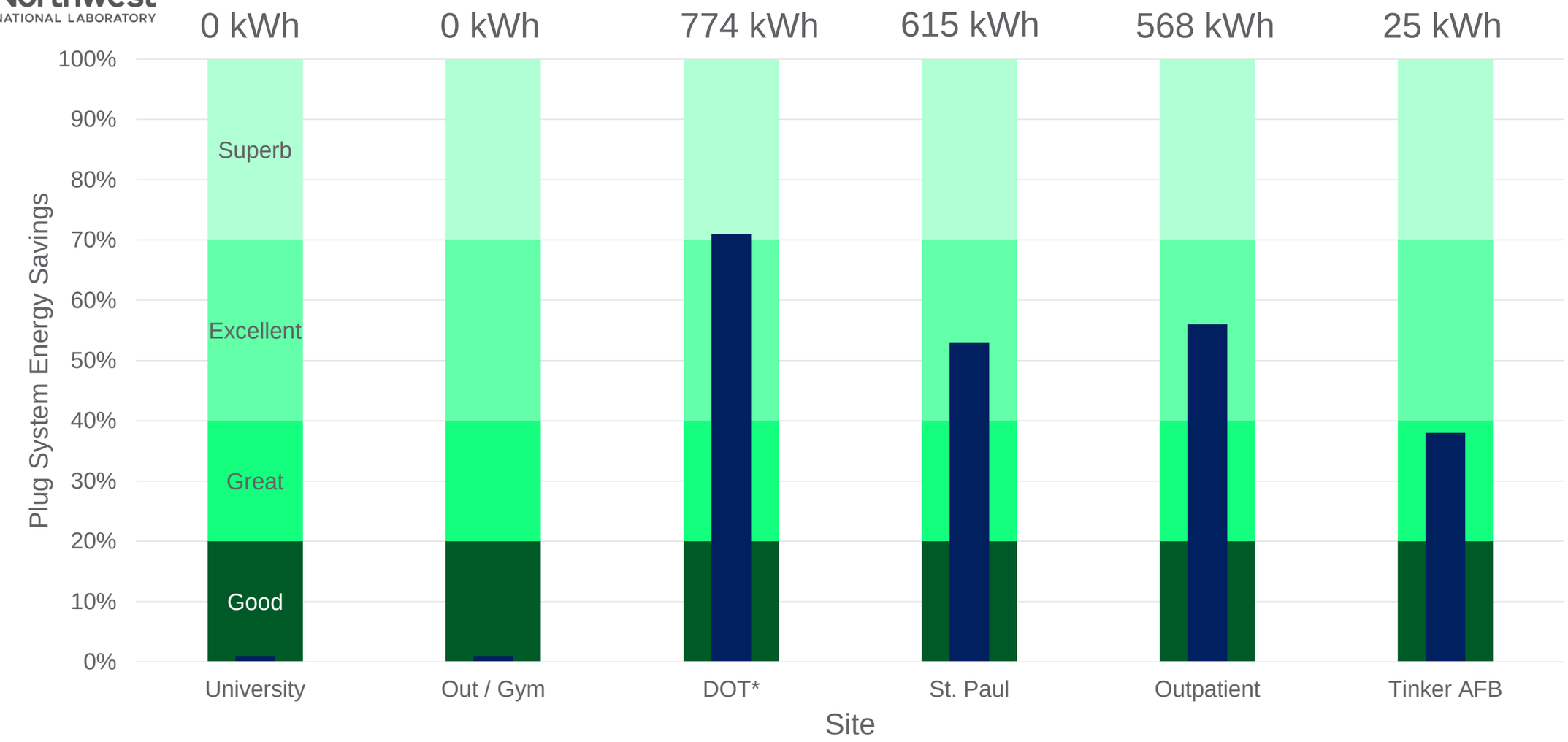
Wireless automatic receptacle controls can introduce issues or additional costs – 3 months lost while reconciling firmware issue



- 5,000 ft^2 portion of office space
- 15 receptacles
- ≈ $160 material per receptacle

- Firmware updates were required – 2 hours per receptacle
- $550 for labor
  - Rewiring of receptacle
  - Mounting controller in box
  - Firmware update

Automatic Receptacle Controls Energy Savings from operational changes

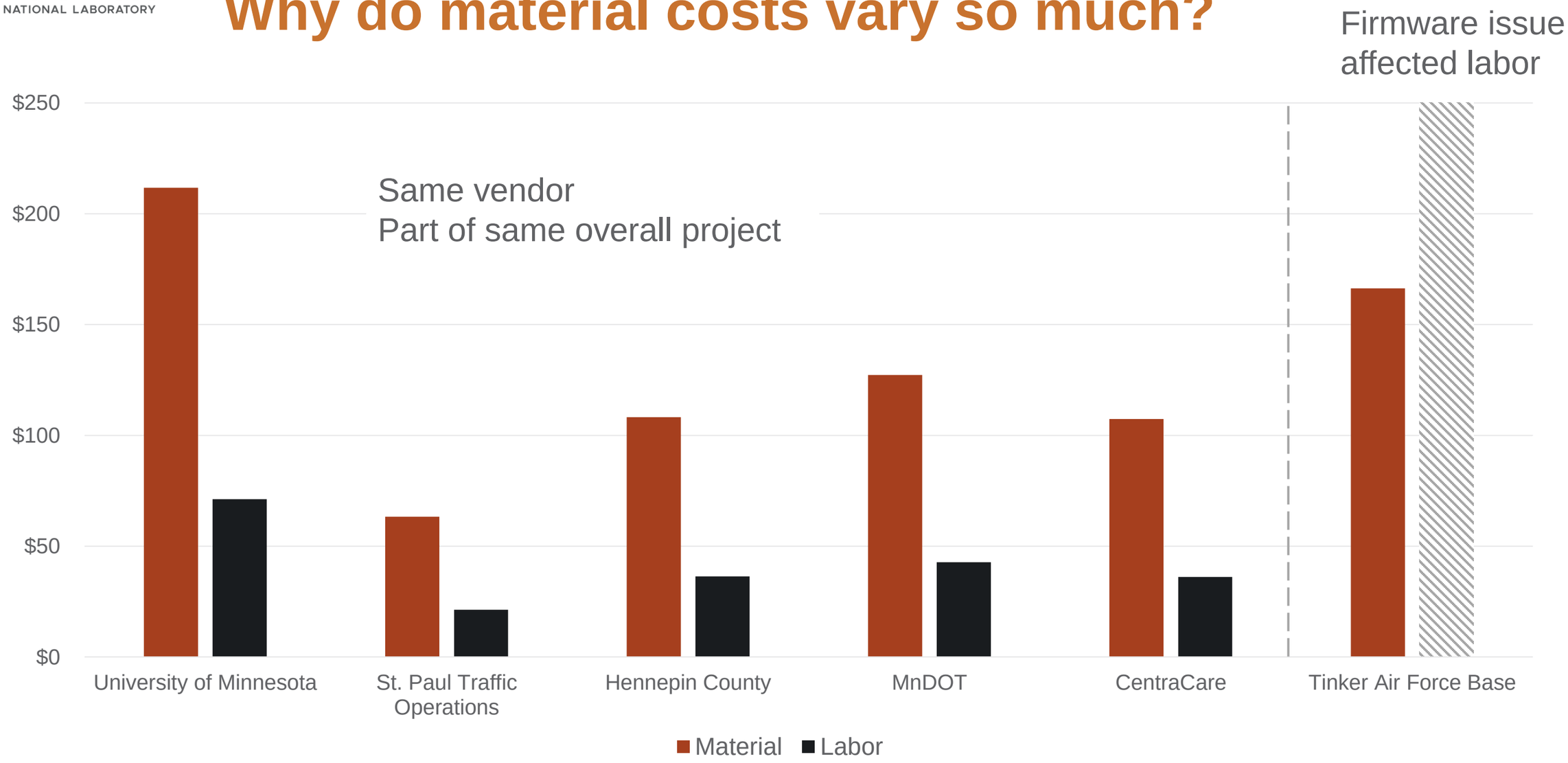


Subjective scale of savings – simply turning off

Red horizontal line indicates targeted savings, black bar indicates achieved savings

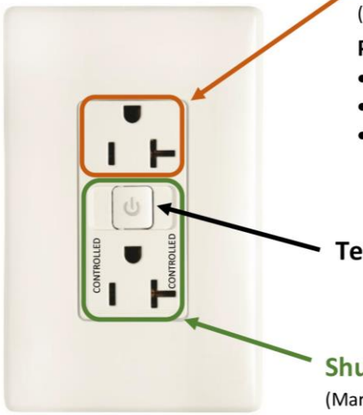
* Post data gathering period occurred during COVID pandemic

6 projects completed in same time period
5 of 6 projects in same metropolis
Why do material costs vary so much?



User Confusion | Guidance showed controlled outlet in bottom, installed 180° opposite to flyer

Your workstation is now equipped with energy-saving electrical outlets that can automatically shut off devices when no one is detected in the room. Identifying which outlets automatically shut off and which always remain powered is important, so you can keep your devices in the appropriate outlet, saving energy without inconvenience.



Constant Power Outlet
(no marking or border)

Plug In:
- Computer CPUs
- Mini-fridges
- Other devices which must always be on or under power

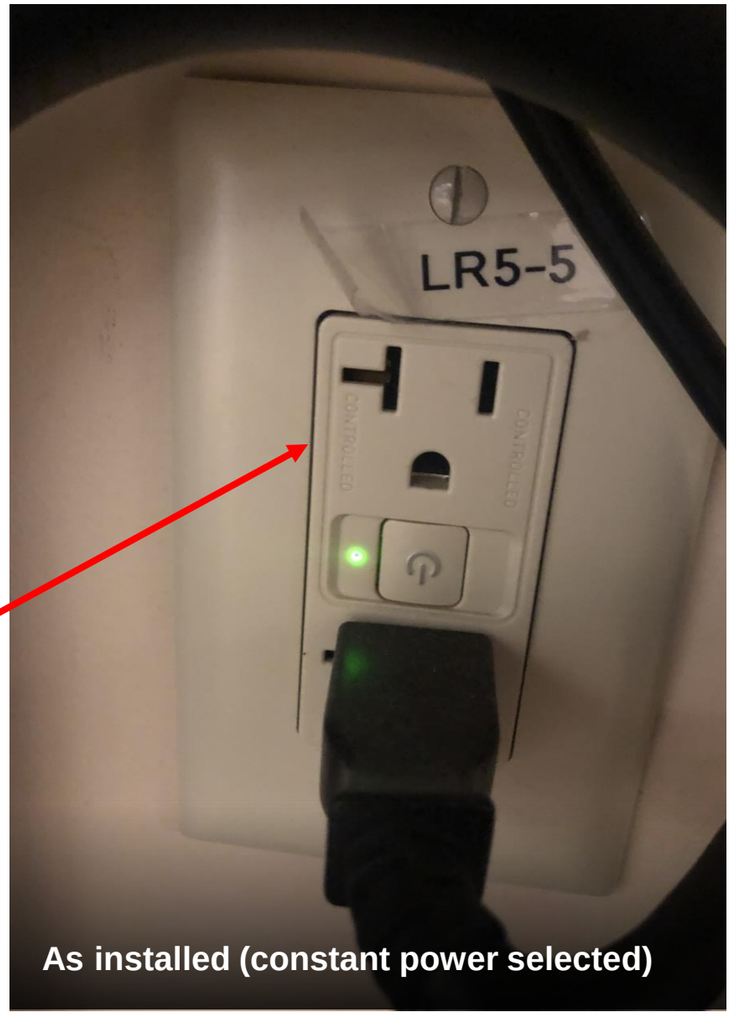
Temporary Override Button

Shut-Off Controlled Outlet
(Marked "CONTROLLED" and outlined with a border)
- Displays/monitors
- Task or exam lights
- Space heaters
- Fans
- Radios/speakers
- Printers
- Hot plates
- Kitchen equipment
- Exercise equipment
- Televisions

NOTE: Outlet may be mounted with Shut-Off CONTROLLED outlet on top. Some outlets have both top and bottom outlets Shut-Off CONTROLLED.

Guidance provided

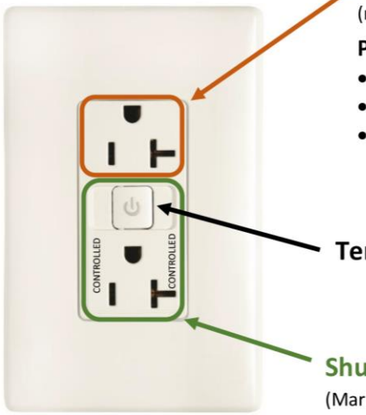
Close-up of receptacle from guidance



As installed (constant power selected)

User Confusion | How much Information to provide?

Your workstation is now equipped with energy-saving electrical outlets that can automatically shut off devices when no one is detected in the room. Identifying which outlets automatically shut off and which always remain powered is important, so you can keep your devices in the appropriate outlet, saving energy without inconvenience.



Constant Power Outlet
(no marking or border)

Plug In:
- Computer CPUs
- Mini-fridges
- Other devices which must always be on or under power

Temporary Override Button

Shut-Off Controlled Outlet
(Marked "CONTROLLED" and outlined with a border)
- Displays/monitors
- Task or exam lights
- Space heaters
- Fans
- Radios/speakers
- Printers
- Hot plates
- Kitchen equipment
- Televisions

NOTE: Outlet may be mounted with Shut-Off CONTROLLED outlet on top. Some outlets have both top and bottom outlets Shut-Off CONTROLLED.

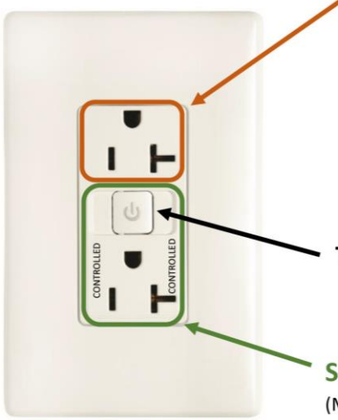
Minnesota site guidance provided to office staff as a flyer

Switched receptacle at outpatient site

Tinker AFB as marked by project

User Confusion | What about other similar looking, but non-controlled receptacles?

Your workstation is now equipped with energy-saving electrical outlets that can automatically shut off devices when no one is detected in the room. Identifying which outlets automatically shut off and which always remain powered is important, so you can keep your devices in the appropriate outlet, saving energy without inconvenience.



Constant Power Outlet
(no marking or border)

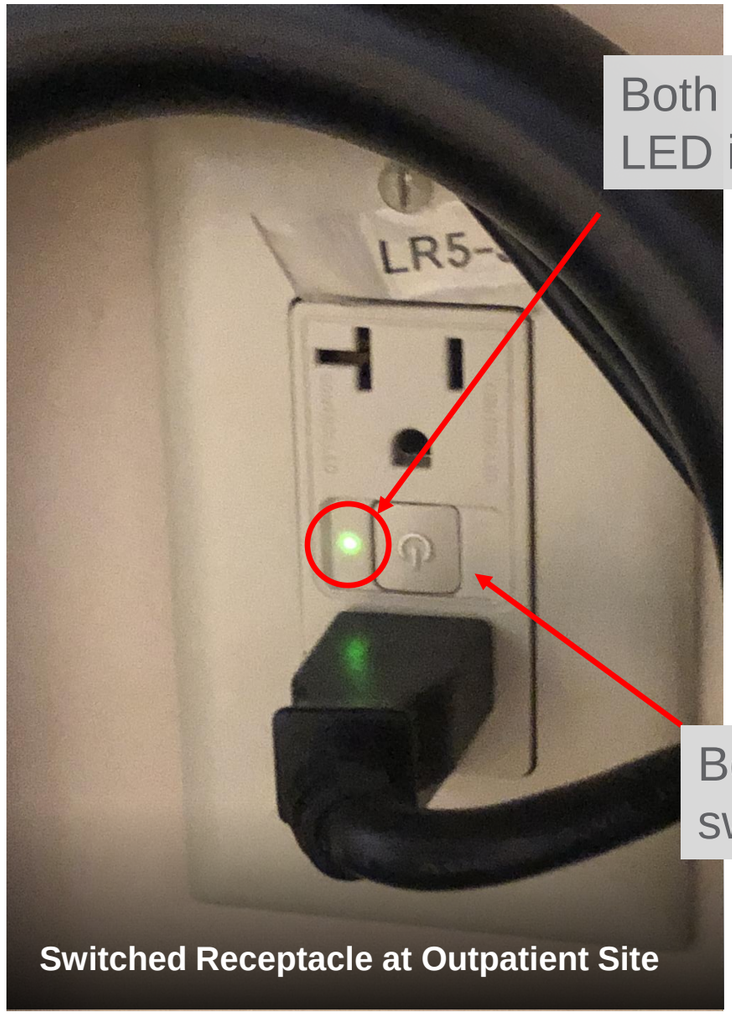
Plug In:
- Computer CPUs
- Mini-fridges
- Other devices which must always be on or under power

Temporary Override Button

Shut-Off Controlled Outlet
(Marked "CONTROLLED" and outlined with a border)
- Displays/monitors
- Task or exam lights
- Space heaters
- Fans
- Radios/speakers
- Printers
- Hot plates
- Kitchen equipment
- Exercise equipment

NOTE: Outlet may be mounted with Shut-Off CONTROLLED outlet on top. Some outlets have both top and bottom outlets Shut-Off CONTROLLED.

Minnesota Site guidance provided

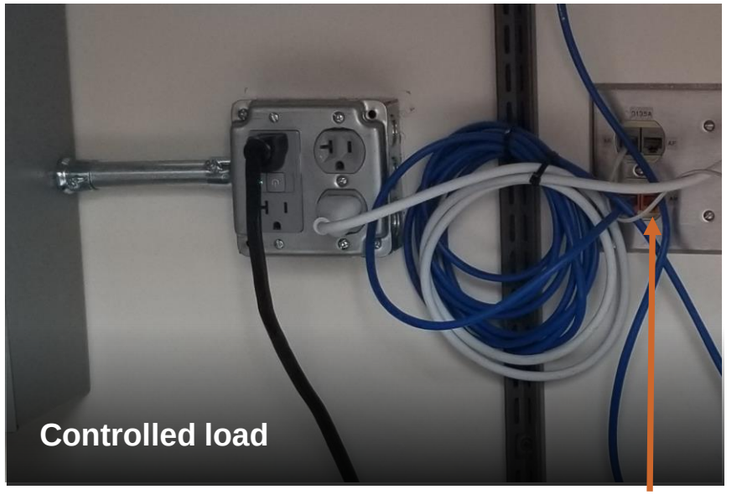


Switched Receptacle at Outpatient Site

GFCI Receptacle at Outpatient Site

User Confusion | Which receptacle to use? No contrasting colors indicating controlled receptacle. Different ethernet ports marked in colors.

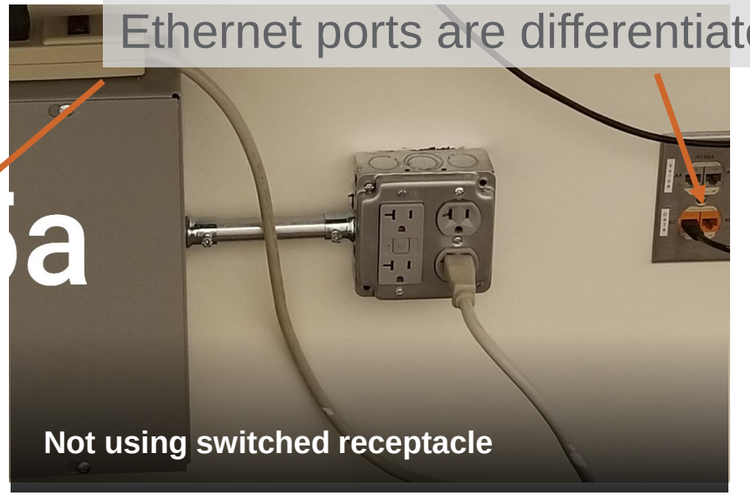

Options

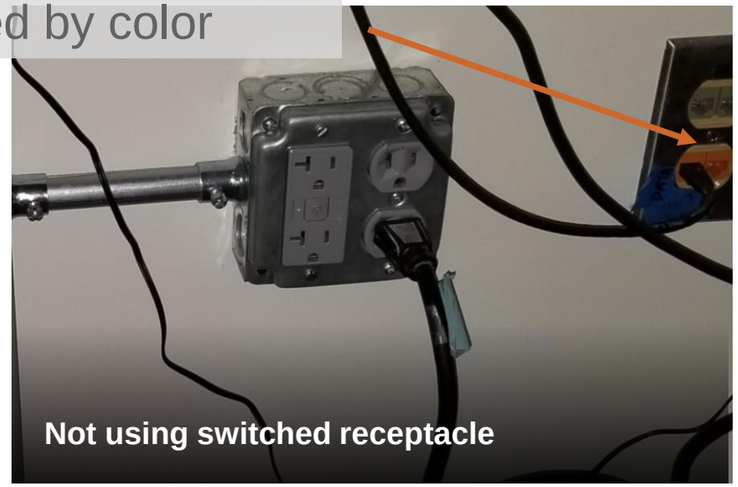

Controlled load


Both controlled and always-on used

Ethernet ports are differentiated by color


Always-on portion of switched receptacle


Not using switched receptacle


Not using switched receptacle

Little consistent markings among manufacturers
Many manufacturers not using contrasting markings

Summary

- Code adoption of controlled receptacles – limited success
- Alternate options for controlled receptacles need to be harder requirement
- Plug loads dwarfing lighting energy use
- Controlled receptacles can be thwarted by occupants
- Savings are mixed (okay %, but low kWh)
- Costs widely mixed for materials & very hard to recover
- Installation errors and confusion occur
- Need better methods for communicating to occupants
- Need better (e.g., contrast) and standardized markings for receptacles

Michael Myer

SENIOR RESEARCHER

Phone: 509.375.7292

Michael.myer@pnnl.gov

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99352

www.pnnl.gov