



Integrating Lighting Within Your Building: Opportunities Ahead

Michael Myer
Senior Researcher



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

PNNL-SA-172234



Michael Myer

Senior Researcher

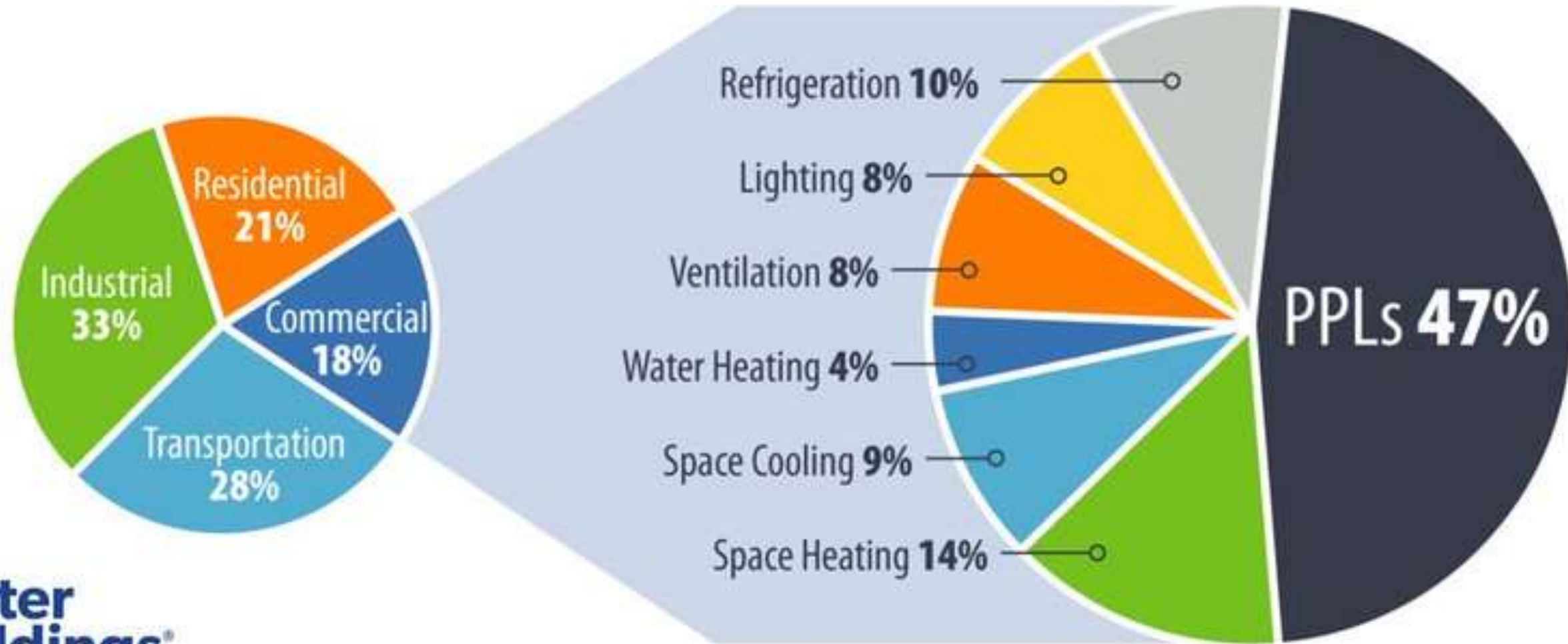
- 15 years at PNNL
- Work: Appliance standards, energy codes, commercial building integration, field studies
- Father, husband, cat wrangler

Agenda

- **Diminishing returns from lighting controls**
- **Summary of Integration**
- **Data from recent projects**
- **Challenges with HVAC integration**
- **Challenges with plug load integration**
- **Summary and recommendations**

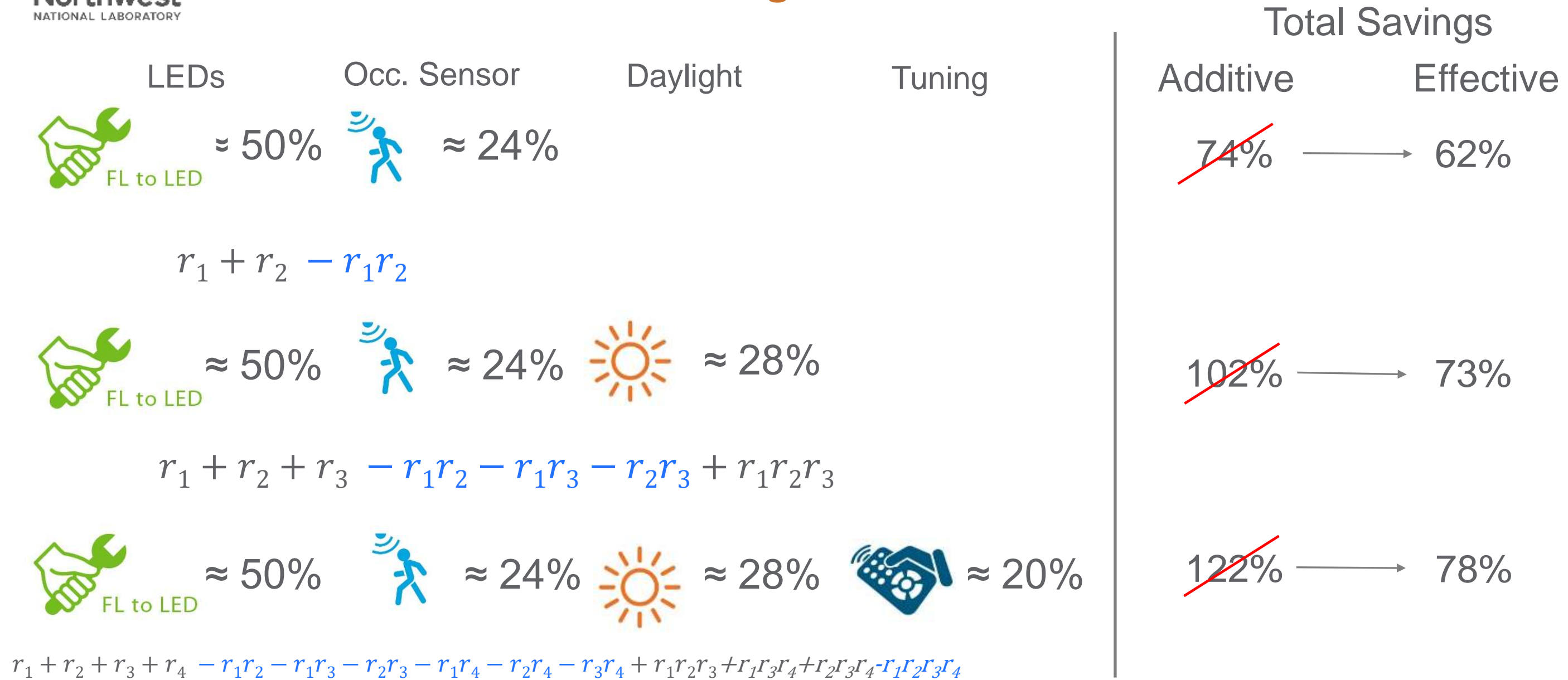
Energy use in buildings is changing:

- 47% | PPLs (Plug & Process loads)
- 32% | HVAC (heating, cooling, ventilation)
- 8% | Lighting



LED lighting & controls can result in diminishing returns

savings are not additive



Effective savings formulas are nominal savings and actual savings will probably be lower because of interactive effects not accounted for in formulas

Typical Energy Savings from Integration

Lighting



≈ 50%
Shift to LED



5 – 25%
Controls

HVAC Integration



- 15 – 70% Savings (more valuable than lighting)
- Temperature, fans, etc. setback in empty spaces
- Dual-use of sensors reduces costs

Plug Loads Controls



- 15 – 50%
- Required by virtually all energy codes in U.S.
- Lighting sensors / schedule allow for control
- Dual-use of controls reduces costs



Government office space (60,000 ft²) lighting integrated with plugs & IoT System

Slower cost recovery from integration

- HVAC integration increased costs, but integration was not successful
- Added costs, w/o reducing payback

Key Takeaways:

- Multi-floor AHUs not ideal for integration
- IoT added benefits

| Lighting | HVAC | Plug | IoT | Total |
|--------------------------|--------------------------|------|-----|--------------------------|
| \$8.76 / ft ² | \$0.92 / ft ² | N/A | TBD | \$9.68 / ft ² |



Military base industrial & office space (26,000 ft²) lighting integrated with HVAC & plugs

85% faster cost recovery from integration

- 18.7-year lighting only simple payback
- 10.3-year lighting + HVAC + plug simple payback

Key Takeaways:

- Found integration easy and found unrelated equipment needing attention in process

| Lighting | HVAC | Plug | Total |
|--------------------------|--------------------------|--------------------------|--------------------------|
| \$3.96 / ft ² | \$0.39 / ft ² | \$0.43 / ft ² | \$4.78 / ft ² |



Fitness center & outpatient medical (7,300 ft²) lighting integrated with HVAC & plugs

30% faster cost recovery from integration

- 25.3-year lighting only simple payback
- 17.6-year lighting + HVAC + plug simple payback

Key Takeaways:

- Efficient lighting baseline affected results

| Lighting | HVAC | Plug | Total |
|--------------------------|--------------------------|--------------------------|--------------------------|
| \$7.00 / ft ² | \$0.38 / ft ² | \$0.20 / ft ² | \$7.58 / ft ² |



Fitness center & outpatient medical (7,300 ft²) lighting integrated with HVAC & plugs

56% faster cost recovery from integration

- 63.2-year lighting only simple payback
- 28.1-year lighting + HVAC + plug simple payback

Key Takeaways:

- Successful integration
- Costly labor because of pharmacy in medical site



| Lighting | HVAC | Plug | Total |
|--------------------------|--------------------------|--------------------------|--------------------------|
| \$7.00 / ft ² | \$0.38 / ft ² | \$0.20 / ft ² | \$7.58 / ft ² |



Light industrial facility (MnDOT) (17,000 ft²) lighting integrated with HVAC & plugs

85% faster cost recovery from integration

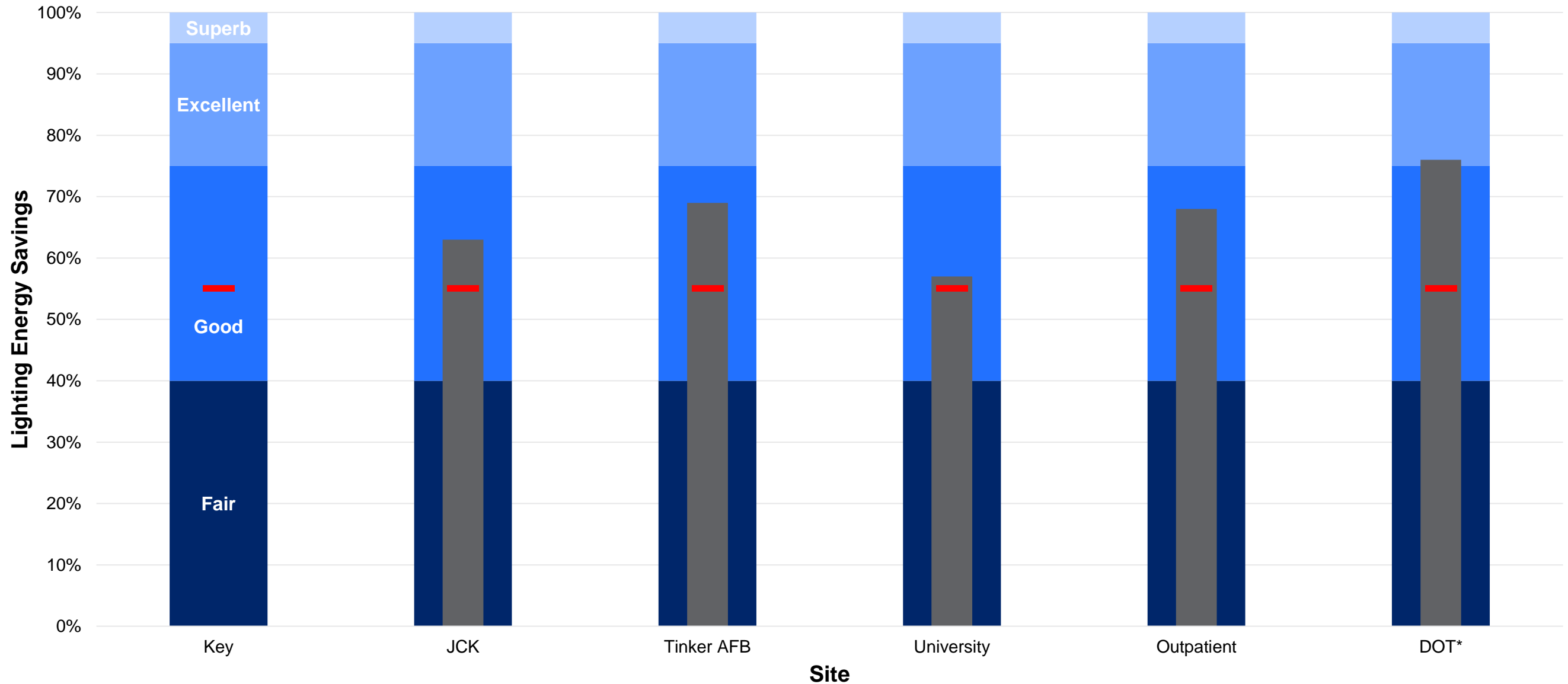
- 39.9-year lighting only simple payback
- 5.8-year lighting + HVAC + plug simple payback

Key Takeaways:

- Savings skewed by building options

| Lighting | HVAC | Plug | Total |
|--------------------------|--------------------------|--------------------------|--------------------------|
| \$7.00 / ft ² | \$0.38 / ft ² | \$0.20 / ft ² | \$7.58 / ft ² |

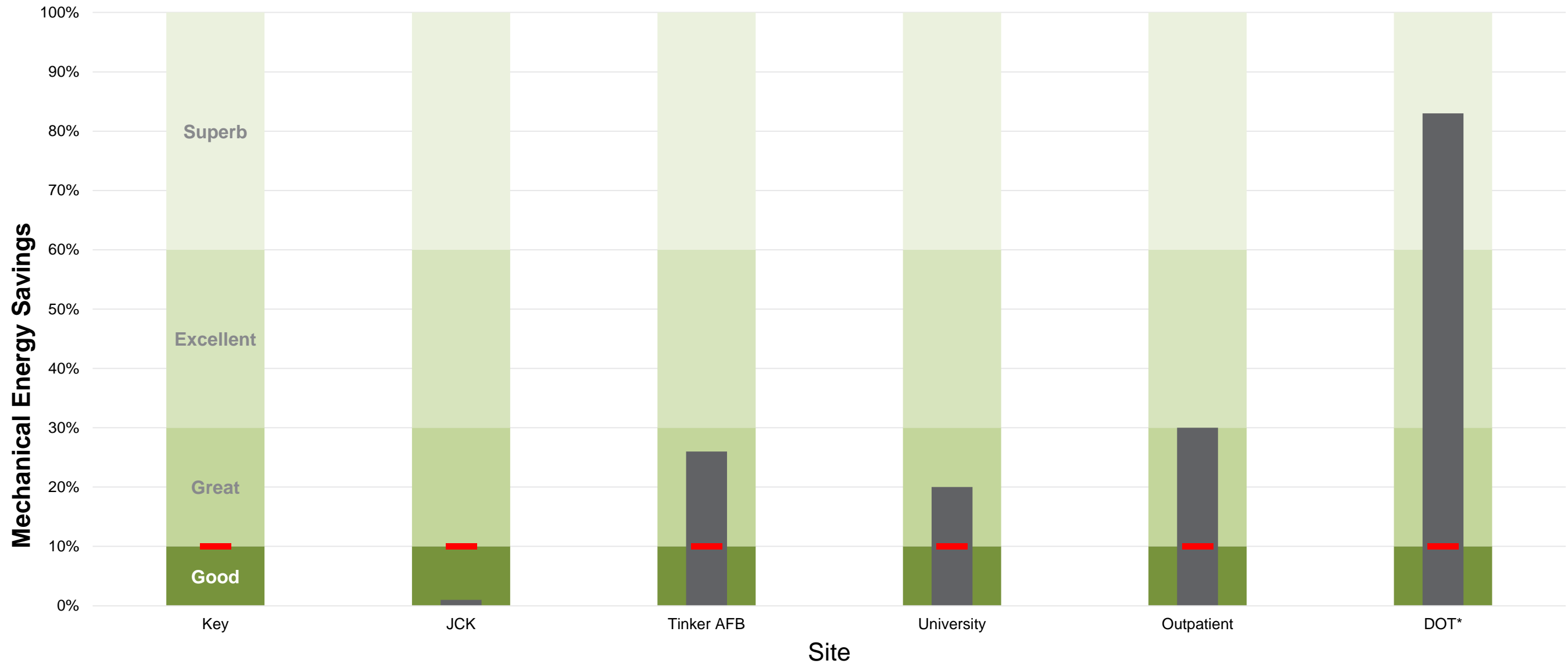
Lighting Energy Savings at 5 Sites



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

* Post data gathering period occurred during COVID pandemic

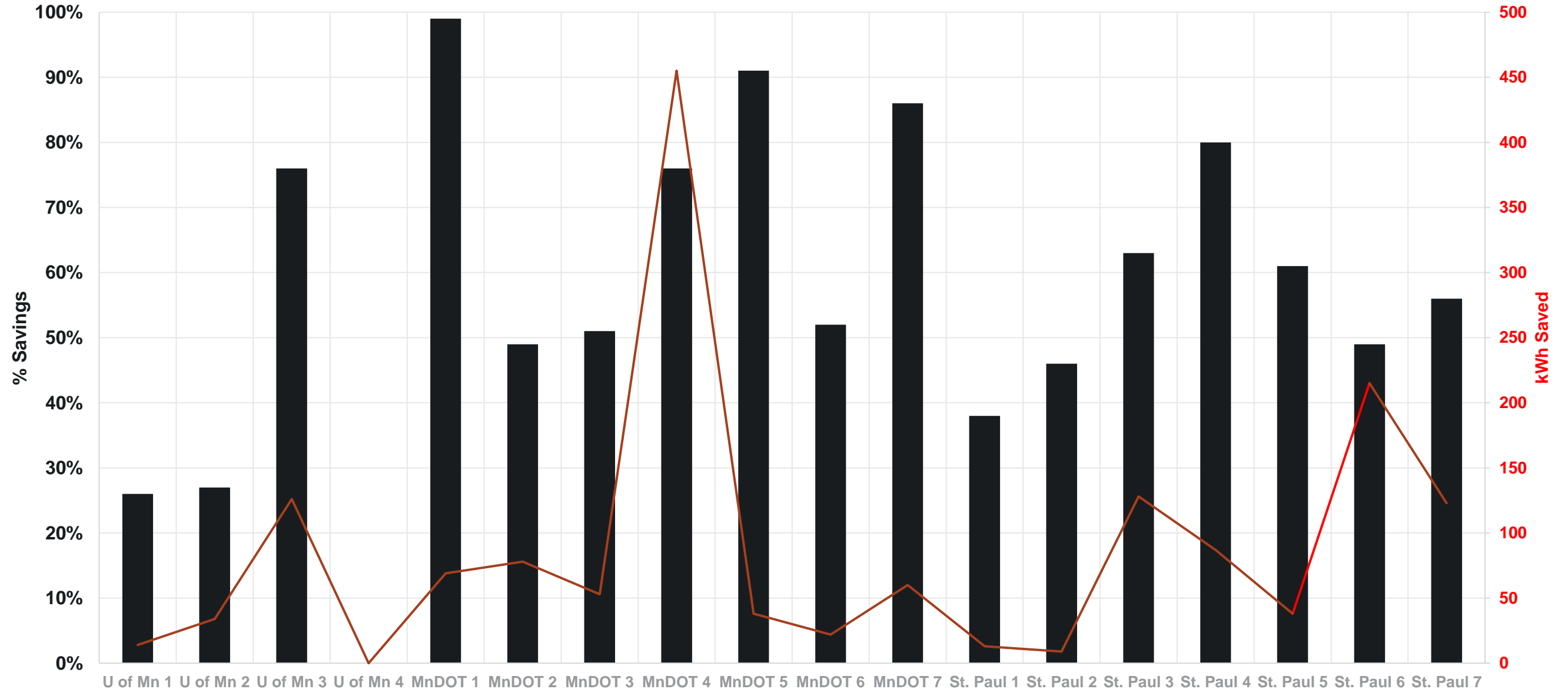
Mechanical System Energy Savings from Integration (operational changes)



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

* Post data gathering period occurred during COVID pandemic

Plug Load Energy Savings from Integration (operational changes)

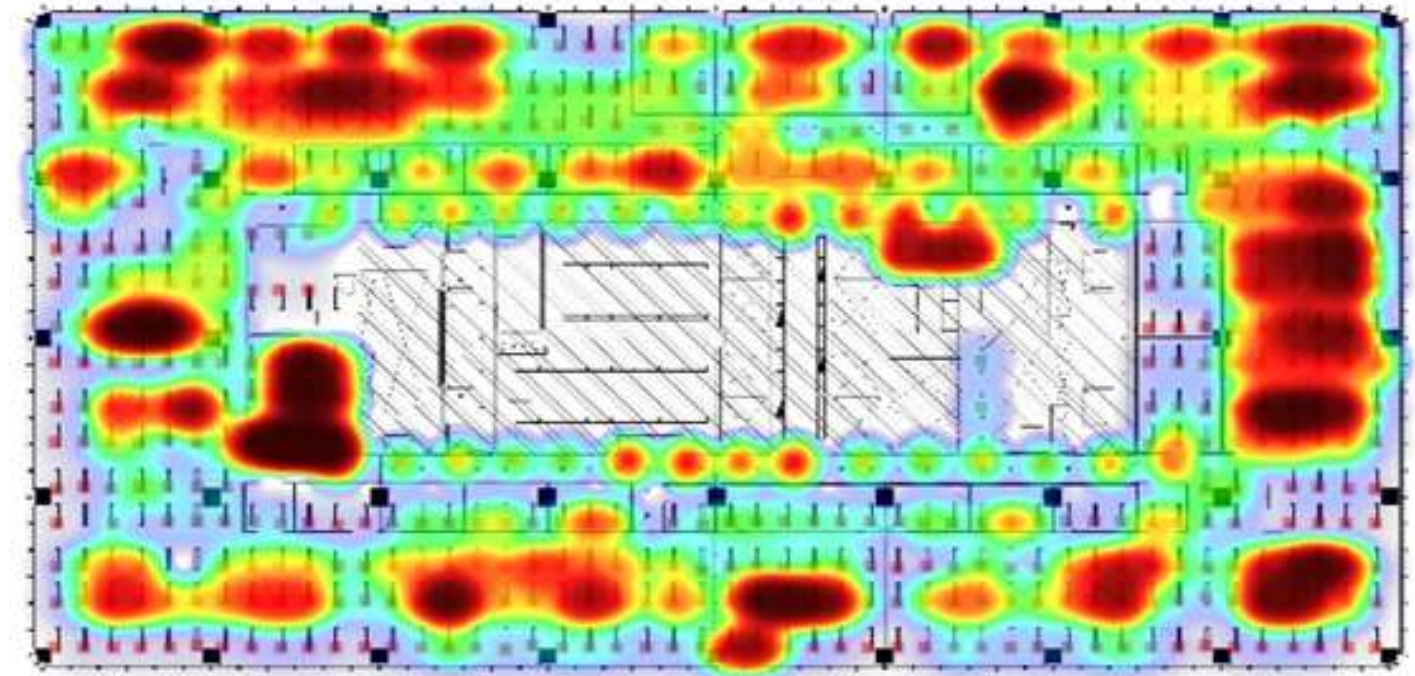


Black bar is % savings, red line is actual kWh saved.





Integration of other systems – using occupancy sensors for space management

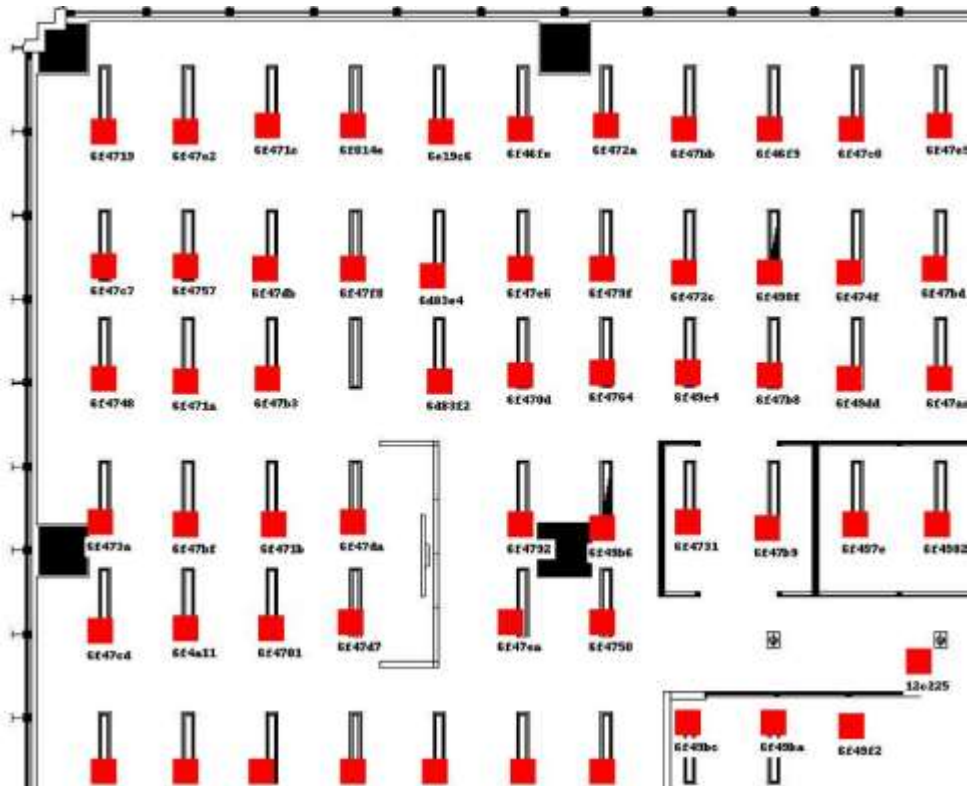
Map of workspace preference

Heat map of occupancy



GSA - 230 S. DEARBORN AVE. C-ICAGO, IL - LEVEL 33

-  LOCATIONS AND SPACES WHERE YOU AVOID WORKING
 -  LOCATIONS AND SPACES YOU'D LIKE TO WORK, BUT SOMETHING IS MISSING
 -  LOCATIONS AND SPACES (OTHER THAN HOME BASE) YOU USE MOST OFTEN
 -  HOME BASE(S)
- EACH ICON INDICATES ONE RESPONSE



Integration / HVAC Challenges:

- Division of labor can lead to integration problems on site.
- Can lead to finger pointing; who is primary?
- Does the mechanical team use the lighting control system to assign the lighting zones?
- Does the lighting / electrical team use the lighting control system to assign the HVAC zones?
- At JCK (image to left), the site mechanical contractor required 300 hours to assist with the integration of the system / project.

HVAC Integration Challenges

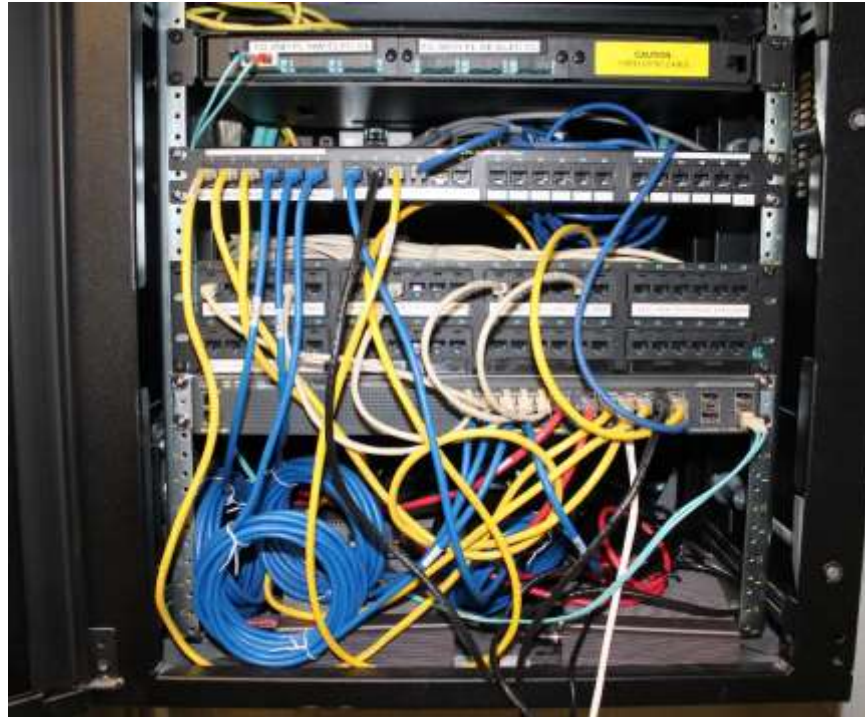
Low data signal is single direction: Multiple steps to determine and track integration



Change in mechanical system should have occurred → system integration stopped

Lighting system indicating space is unoccupied

During a cold week, occupants manually changed the temperature and that caused the integration to stop, but unknown to building until we analyzed the data



Integration of HVAC Availability Options by multiple manufacturers:

- Relies on BACnet integration
- BACnet common in many buildings
- Many buildings also use building automation systems (BAS)
- Requires the lighting system to be networked
- Requires the lighting system to product a BACnet symbol
- Multiple major control systems offer this feature



Photos of John C. Kluczynski Federal Building
& US Post Office, Loop Station

Integration / Suitable HVAC Applications:

- Operational mechanical savings – low cost saving
- Not suitable / ideal for all buildings
- Good Applications
 - Variable flow devices
 - Small zones
- Less Ideal Applications
 - Building with multiple systems serving same zones
 - Buildings with AHUs serving multiple floors

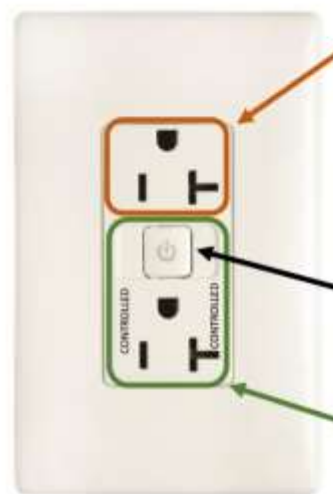


Integration / Plug Load Challenges :

- Cost recovery
- Low energy savings but high % savings
- Users can thwart controls
- User confusion
 - Which is controlled receptacle
 - Which is controlled outlet
- Devices
 - Which devices are ideal for controlled receptacles?
 - How to determine if a device has a long warm-up period?
- New California Title 24 demand response receptacles

Integration of Plug Load Challenges: User Confusion

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)

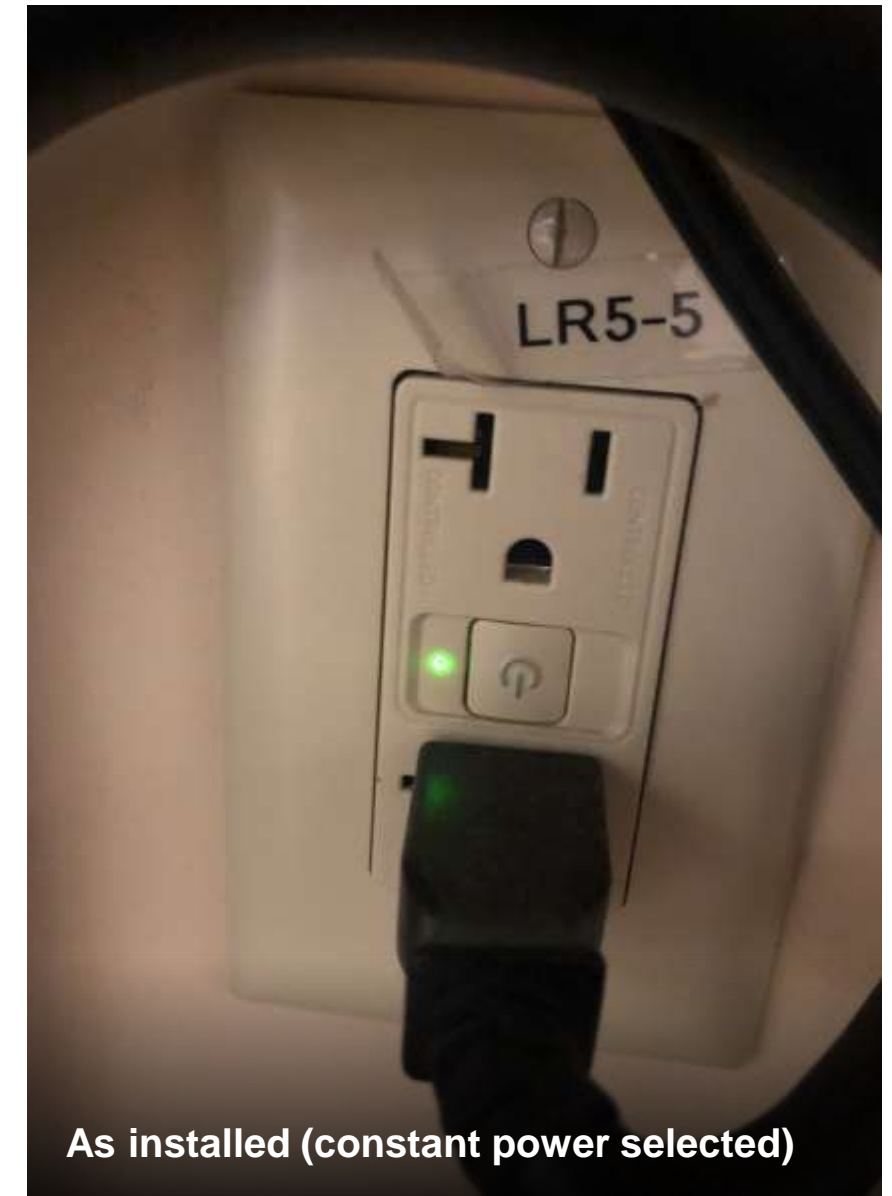
- Displays/monitors
- Task or exam lights
- Space heaters
- Fans
- Radios/speakers
- Printers
- Hot plates
- Kitchen equipment
- Exercise equipment
- Televisions

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

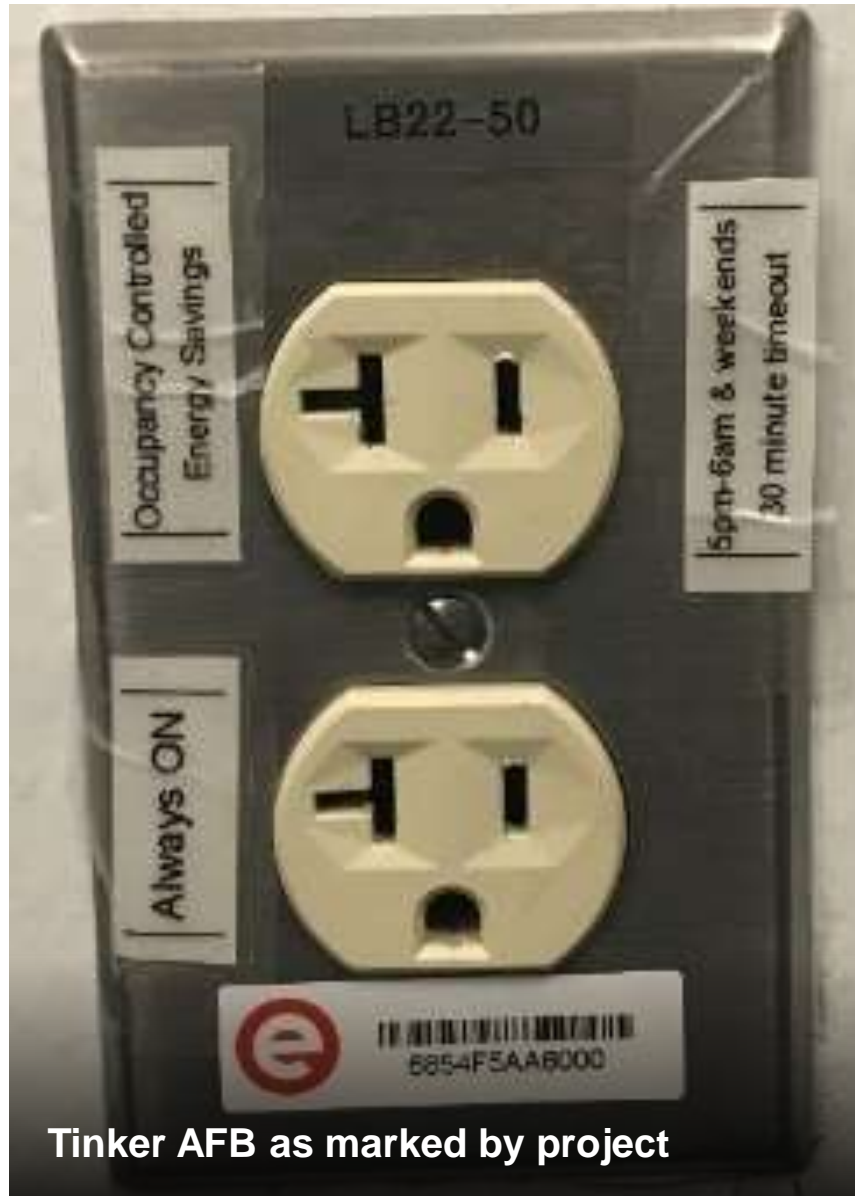


Close-up of receptacle from guidance



As installed (constant power selected)

Integration of Plug Load Challenges: User Confusion



Tinker AFB as marked by project



Switched Receptacle at Outpatient Site



GFCI Receptacle at Outpatient Site

Integration of Plug Load Product Availability Options by multiple manufacturers





Minimum



Better



Best

Integration / Suitable Plug Load Applications:

- Controlled receptacles with contrasting markings to indicate controlled receptacle (see “better”)
- Outlet clearly identified with contrast (see “best”)
- Devices have markings on plugs indicating that they are suitable for controlled receptacles
- Medium and high-power devices with no warm-up period or connectivity being controlled

Needs to advance integration

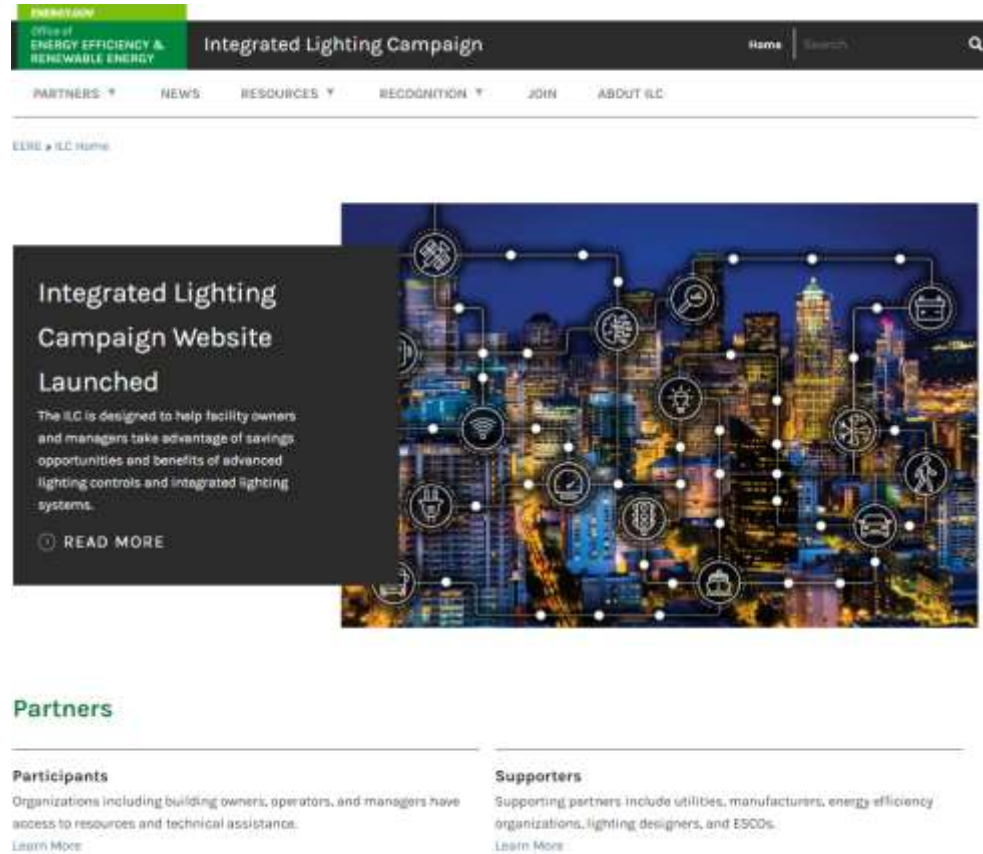
- Better methods for determining integration success
- Method for continuing to know systems are integrated
- Better estimates for energy savings from integration
- Less costly methods for determining savings
- Better agreement of trades or increase role of integrators
- Lighting controls failure notifications

Summary

- Integrating with other building systems improves the cost effectiveness of the lighting system
- Integration *can be* simple
- Integration *can be* challenging

- Integrating lighting with HVAC and plug loads can yield significant portion of energy savings
- Energy savings of integrating with HVAC depends on the building type and mechanical system

- Controlled plug loads struggle with cost effectiveness



Integrated Lighting Campaign

<https://integratedlightingcampaign.energy.gov>

Guidance and recognition program

Recognized utility and program implementers



**Pacific
Northwest**
NATIONAL LABORATORY

Michael Myer

SENIOR RESEARCHER

Phone: 509.375.7292

Michael.myer@pnnl.gov

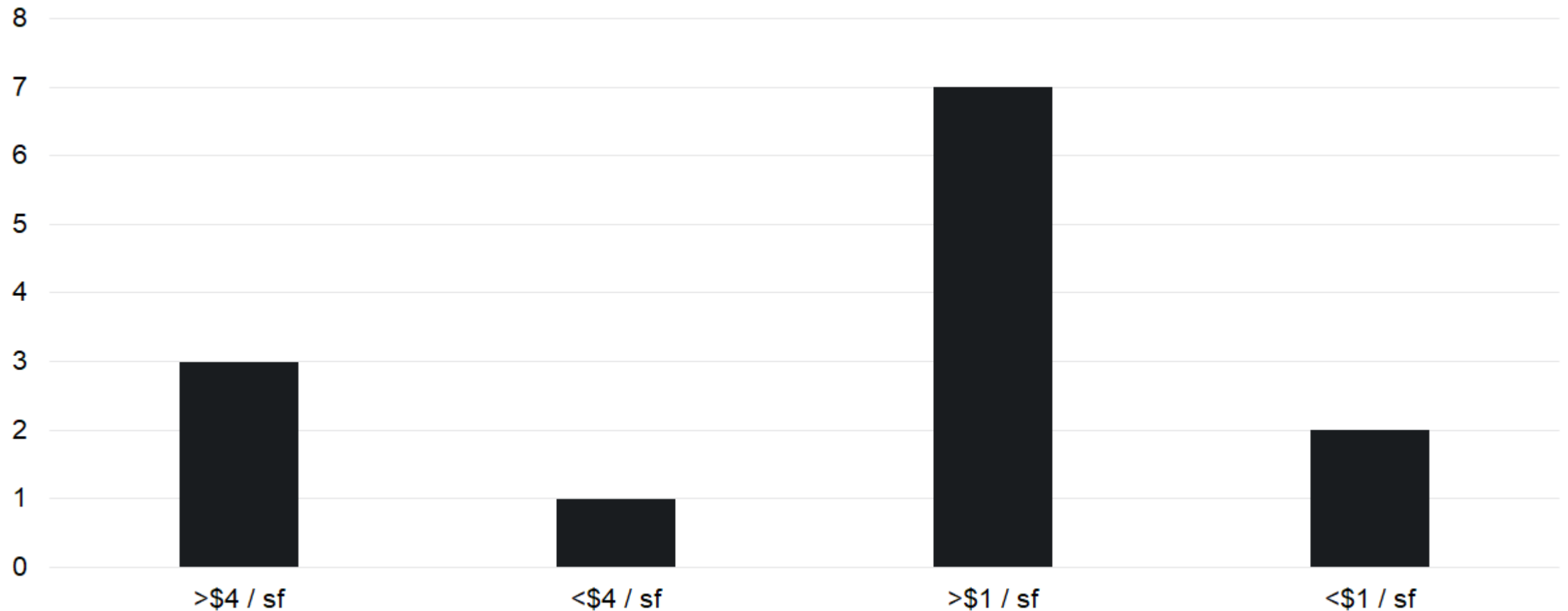
902 Battelle Boulevard

P.O. Box 999

Richland, WA 99352

www.pnnl.gov

How much would you pay for the IoT System? What is the value per square foot (sf)?



Sample size (≈ 30) of GSA staff with various jobs

Recommendations

- **25,000 ft² buildings:** fixed costs and staffing needs suggest integration is not currently ideal
- **50,000 ft² buildings:** should consider integration
- **Plug loads:** integrating with plug loads helps with energy code compliance, but may be hard to recover costs (controlled receptacles are expensive)
- **HVAC integration:** can reduce cost recovery time of the connected lighting system by 30% or more
- **Integrators:** consider having an integrator assist on the project
- **Tools:** building operators need more tools to track integration over time