# Better Together: Integrating Plug Load Management into Lighting and Building Management Systems

## Better Buildings Alliance Plug and Process Loads (PPLs) Team Webinar

Technical Lead: Dr. Kim Trenbath, NREL

March 22, 2022

# Agenda

BBA PPL Team Update

Integrated Lighting Campaign – Axel Pearson, Pacific Northwest National Laboratory

Technical Presentation – Mark Moehlenbrock, PE, Minnesota Department of Transportation
Plug Load Control Integration at Minnesota Department of Transportation

Technical Presentation – Dr. Jan Kleissl and Keaton Chia, UC San Diego
Smart Plug Load Controls Integrated with a Building Energy Management System

Q&A

# Plug and Process Loads (PPL) Technology Research Team

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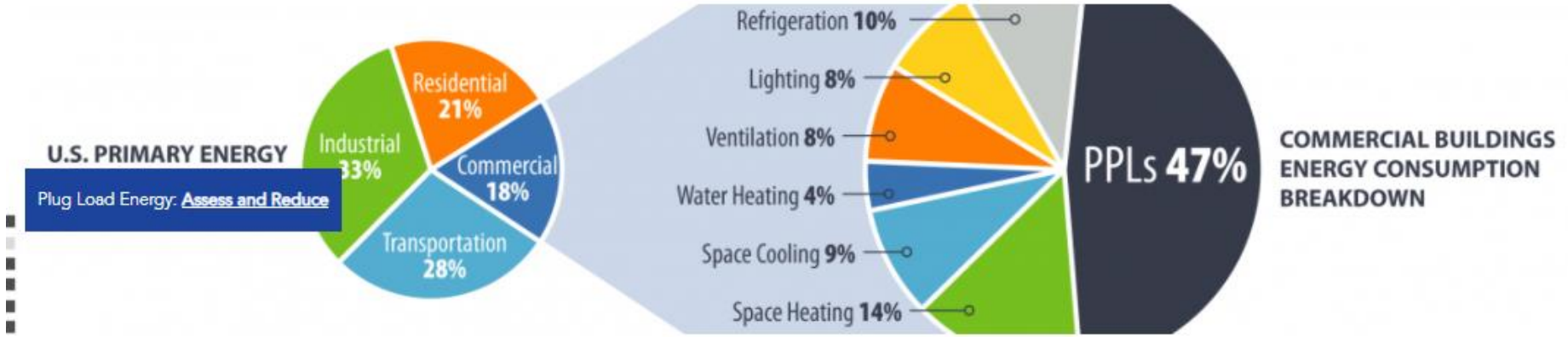
# BBA PPL Team Update

# Plug & Process Loads Website

https://betterbuildingssolutioncenter.energy.gov/alliance/technology-solution/plug-process-loads

Plug and process loads (PPLs) consume about 47% of primary energy in U.S. commercial buildings. As buildings become more efficient, PPL efficiency has become pertinent in achieving aggressive energy targets. Through the PPL Technology Research Team, partners participate in a platform to share experiences and learn from their peers and work together to create resources on PPL energy reduction strategies and their applications, covering a wide variety of electronic, computer, refrigeration, and cooking devices, including equipment essential to information processing, medical treatment, and foodservice businesses.



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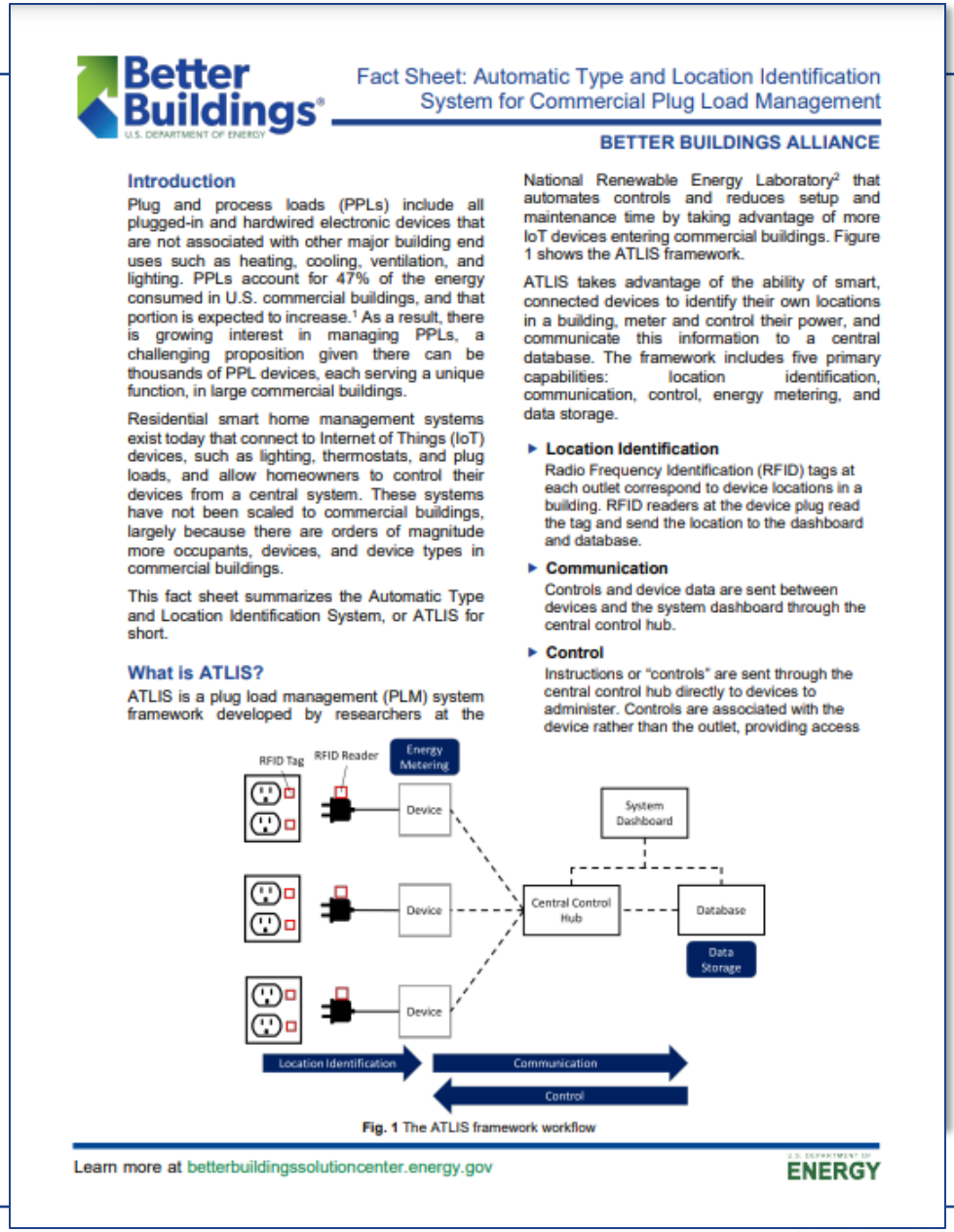
# NEW Fact Sheet

- Describe the **Automatic Type and Location Identification System (ATLIS)** for Commercial Building Plug Load Management
- Plug-and-play system framework that
  1. tracks devices as they move through a building
  2. accurately applies controls
  3. monitors device energy.
- Fact sheet can be found in our Featured Solutions



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Fact Sheet: Automatic Type and Location Identification System for Commercial Plug Load Management

BETTER BUILDINGS ALLIANCE

**Introduction**

Plug and process loads (PPLs) include all plugged-in and hardwired electronic devices that are not associated with other major building end uses such as heating, cooling, ventilation, and lighting. PPLs account for 47% of the energy consumed in U.S. commercial buildings, and that portion is expected to increase.[1] As a result, there is growing interest in managing PPLs, a challenging proposition given there can be thousands of PPL devices, each serving a unique function, in large commercial buildings.

Residential smart home management systems exist today that connect to Internet of Things (IoT) devices, such as lighting, thermostats, and plug loads, and allow homeowners to control their devices from a central system. These systems have not been scaled to commercial buildings, largely because there are orders of magnitude more occupants, devices, and device types in commercial buildings.

This fact sheet summarizes the Automatic Type and Location Identification System, or ATLIS for short.

**What is ATLIS?**

ATLIS is a plug load management (PLM) system framework developed by researchers at the National Renewable Energy Laboratory[2] that automates controls and reduces setup and maintenance time by taking advantage of more IoT devices entering commercial buildings. Figure 1 shows the ATLIS framework.

ATLIS takes advantage of the ability of smart, connected devices to identify their own locations in a building, meter and control their power, and communicate this information to a central database. The framework includes five primary capabilities: location identification, communication, control, energy metering, and data storage.

- **Location Identification**
  Radio Frequency Identification (RFID) tags at each outlet correspond to device locations in a building. RFID readers at the device plug read the tag and send the location to the dashboard and database.
- **Communication**
  Controls and device data are sent between devices and the system dashboard through the central control hub.
- **Control**
  Instructions or "controls" are sent through the central control hub directly to devices to administer. Controls are associated with the device rather than the outlet, providing access



**Fig. 1** The ATLIS framework workflow

Learn more at betterbuildingssolutioncenter.energy.gov

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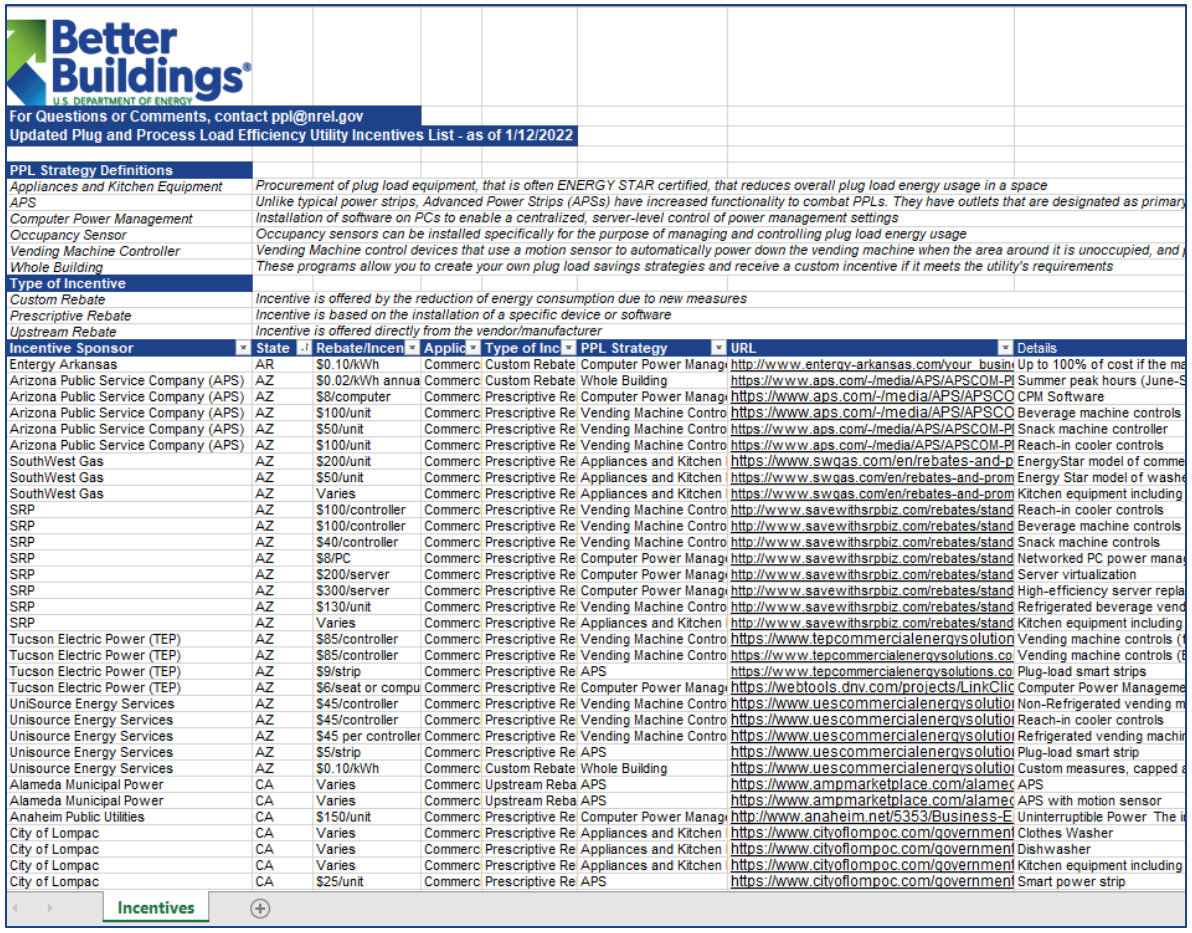
# UPDATED PPL Utility Incentives

- Over 500 PPL incentives listed from 42 states
- Common PPL incentive strategies include:
  - Appliances & Kitchen Equipment
  - Advanced Power Strips
  - Computer Power Management
  - Occupancy Sensors
  - Vending Machine Controllers
  - Whole Building
- PPL Utility Incentives can be found under Policies and Incentives on the PPL website



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For Questions or Comments, contact ppl@nrel.gov

Updated Plug and Process Load Efficiency Utility Incentives List - as of 1/12/2022

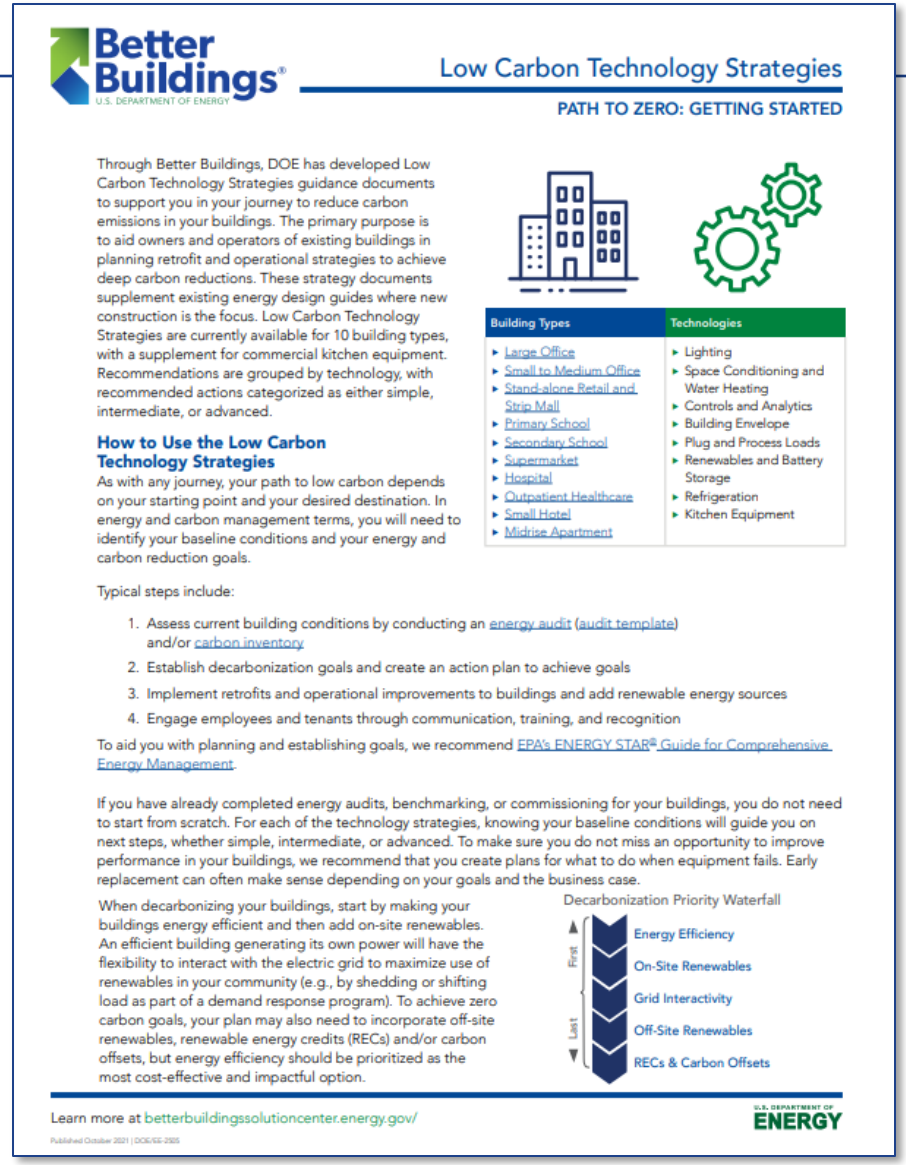
| PPL Strategy Definitions | |
|---|---|
| *Appliances and Kitchen Equipment* | *Procurement of plug load equipment, that is often ENERGY STAR certified, that reduces overall plug load energy usage in a space* |
| *APS* | *Unlike typical power strips, Advanced Power Strips (APSs) have increased functionality to combat PPLs. They have outlets that are designated as primary* |
| *Computer Power Management* | *Installation of software on PCs to enable a centralized, server-level control of power management settings* |
| *Occupancy Sensor* | *Occupancy sensors can be installed specifically for the purpose of managing and controlling plug load energy usage* |
| *Vending Machine Controller* | *Vending Machine control devices that use a motion sensor to automatically power down the vending machine when the area around it is unoccupied, and* |
| *Whole Building* | *These programs allow you to create your own plug load savings strategies and receive a custom incentive if it meets the utility's requirements* |
| **Type of Incentive** | |
| *Custom Rebate* | *Incentive is offered by the reduction of energy consumption due to new measures* |
| *Prescriptive Rebate* | *Incentive is based on the installation of a specific device or software* |
| *Upstream Rebate* | *Incentive is offered directly from the vendor/manufacturer* |

| Incentive Sponsor | State | Rebate/Incen | Applic | Type of Inc | PPL Strategy | URL | Details |
|---|---|---|---|---|---|---|---|
| Entergy Arkansas | AR | $0.10/kWh | Commerc | Custom Rebate | Computer Power Manag | http://www.entergy-arkansas.com/your_busin | Up to 100% of cost if the m |
| Arizona Public Service Company (APS) | AZ | $0.02/kWh annua | Commerc | Custom Rebate | Whole Building | https://www.aps.com/-/media/APS/APSCOM-Pl | Summer peak hours (June-S |
| Arizona Public Service Company (APS) | AZ | $8/computer | Commerc | Prescriptive Re | Computer Power Manag | https://www.aps.com/-/media/APS/APSCO | CPM Software |
| Arizona Public Service Company (APS) | AZ | $100/unit | Commerc | Prescriptive Re | Vending Machine Contro | https://www.aps.com/-/media/APS/APSCO | Beverage machine controls |
| Arizona Public Service Company (APS) | AZ | $50/unit | Commerc | Prescriptive Re | Vending Machine Contro | https://www.aps.com/-/media/APS/APSCOM-Pl | Snack machine controller |
| Arizona Public Service Company (APS) | AZ | $100/unit | Commerc | Prescriptive Re | Vending Machine Contro | https://www.aps.com/-/media/APS/APSCOM-Pl | Reach-in cooler controls |
| SouthWest Gas | AZ | $200/unit | Commerc | Prescriptive Re | Appliances and Kitchen | https://www.swgas.com/en/rebates-and-p | EnergyStar model of comme |
| SouthWest Gas | AZ | $50/unit | Commerc | Prescriptive Re | Appliances and Kitchen | https://www.swgas.com/en/rebates-and-prom | Energy Star model of washe |
| SouthWest Gas | AZ | Varies | Commerc | Prescriptive Re | Appliances and Kitchen | https://www.swgas.com/en/rebates-and-prom | Kitchen equipment including |
| SRP | AZ | $100/controller | Commerc | Prescriptive Re | Vending Machine Contro | http://www.savewithsrpbiz.com/rebates/stand | Reach-in cooler controls |
| SRP | AZ | $100/controller | Commerc | Prescriptive Re | Vending Machine Contro | http://www.savewithsrpbiz.com/rebates/stand | Beverage machine controls |
| SRP | AZ | $40/controller | Commerc | Prescriptive Re | Vending Machine Contro | http://www.savewithsrpbiz.com/rebates/stand | Snack machine controls |
| SRP | AZ | $8/PC | Commerc | Prescriptive Re | Computer Power Manag | http://www.savewithsrpbiz.com/rebates/stand | Networked PC power mana |
| SRP | AZ | $200/server | Commerc | Prescriptive Re | Computer Power Manag | http://www.savewithsrpbiz.com/rebates/stand | Server virtualization |
| SRP | AZ | $300/server | Commerc | Prescriptive Re | Computer Power Manag | http://www.savewithsrpbiz.com/rebates/stand | High-efficiency server repla |
| SRP | AZ | $130/unit | Commerc | Prescriptive Re | Vending Machine Contro | http://www.savewithsrpbiz.com/rebates/stand | Refrigerated beverage vend |
| SRP | AZ | Varies | Commerc | Prescriptive Re | Appliances and Kitchen | http://www.savewithsrpbiz.com/rebates/stand | Kitchen equipment including |
| Tucson Electric Power (TEP) | AZ | $85/controller | Commerc | Prescriptive Re | Vending Machine Contro | https://www.tepcommercialenergysolution | Vending machine controls ( |
| Tucson Electric Power (TEP) | AZ | $85/controller | Commerc | Prescriptive Re | Vending Machine Contro | https://www.tepcommercialenergysolutions.co | Vending machine controls ( |
| Tucson Electric Power (TEP) | AZ | $9/strip | Commerc | Prescriptive Re | APS | https://www.tepcommercialenergysolutions.co | Plug-load smart strips |
| Tucson Electric Power (TEP) | AZ | $6/seat or compu | Commerc | Prescriptive Re | Computer Power Manag | https://webtools.dnv.com/projects/LinkClic | Computer Power Manageme |
| UniSource Energy Services | AZ | $45/controller | Commerc | Prescriptive Re | Vending Machine Contro | https://www.uescommercialenergysolutio | Non-Refrigerated vending m |
| Unisource Energy Services | AZ | $45/controller | Commerc | Prescriptive Re | Vending Machine Contro | https://www.uescommercialenergysolutio | Reach-in cooler controls |
| Unisource Energy Services | AZ | $45 per controller | Commerc | Prescriptive Re | Vending Machine Contro | https://www.uescommercialenergysolutio | Refrigerated vending machi |
| Unisource Energy Services | AZ | $5/strip | Commerc | Prescriptive Re | APS | https://www.uescommercialenergysolutio | Plug-load smart strip |
| Unisource Energy Services | AZ | $0.10/kWh | Commerc | Custom Rebate | Whole Building | https://www.uescommercialenergysolutio | Custom measures, capped |
| Alameda Municipal Power | CA | Varies | Commerc | Upstream Reba | APS | https://www.ampmarketplace.com/alame | APS |
| Alameda Municipal Power | CA | Varies | Commerc | Upstream Reba | APS | https://www.ampmarketplace.com/alame | APS with motion sensor |
| Anaheim Public Utilities | CA | $150/unit | Commerc | Prescriptive Re | Computer Power Manag | http://www.anaheim.net/5353/Business-E | Uninterruptible Power The |
| City of Lompac | CA | Varies | Commerc | Prescriptive Re | Appliances and Kitchen | https://www.cityoflompoc.com/government | Clothes Washer |
| City of Lompac | CA | Varies | Commerc | Prescriptive Re | Appliances and Kitchen | https://www.cityoflompoc.com/government | Dishwasher |
| City of Lompac | CA | Varies | Commerc | Prescriptive Re | Appliances and Kitchen | https://www.cityoflompoc.com/government | Kitchen equipment including |
| City of Lompac | CA | $25/unit | Commerc | Prescriptive Re | APS | https://www.cityoflompoc.com/government | Smart power strip |

Incentives

# PPL Resources for Building Owners

- The PPL Team worked alongside DOE in developing **Low Carbon Technology Strategies** guidance documents
- Documents will aid owners and operators of existing buildings in planning retrofit and operational strategies to achieve deep carbon reductions
- Toolkit can be found on the BBA website



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Low Carbon Technology Strategies

PATH TO ZERO: GETTING STARTED

Through Better Buildings, DOE has developed Low Carbon Technology Strategies guidance documents to support you in your journey to reduce carbon emissions in your buildings. The primary purpose is to aid owners and operators of existing buildings in planning retrofit and operational strategies to achieve deep carbon reductions. These strategy documents supplement existing energy design guides where new construction is the focus. Low Carbon Technology Strategies are currently available for 10 building types, with a supplement for commercial kitchen equipment. Recommendations are grouped by technology, with recommended actions categorized as either simple, intermediate, or advanced.

| Building Types | Technologies |
|---|---|
| Large Office | Lighting |
| Small to Medium Office | Space Conditioning and Water Heating |
| Stand-alone Retail and Strip Mall | Controls and Analytics |
| Primary School | Building Envelope |
| Secondary School | Plug and Process Loads |
| Supermarket | Renewables and Battery Storage |
| Hospital | Refrigeration |
| Outpatient Healthcare | Kitchen Equipment |
| Small Hotel | |
| Midrise Apartment | |

**How to Use the Low Carbon Technology Strategies**

As with any journey, your path to low carbon depends on your starting point and your desired destination. In energy and carbon management terms, you will need to identify your baseline conditions and your energy and carbon reduction goals.

Typical steps include:

1. Assess current building conditions by conducting an energy audit (audit template) and/or carbon inventory
2. Establish decarbonization goals and create an action plan to achieve goals
3. Implement retrofits and operational improvements to buildings and add renewable energy sources
4. Engage employees and tenants through communication, training, and recognition

To aid you with planning and establishing goals, we recommend EPA's ENERGY STAR® Guide for Comprehensive Energy Management.

If you have already completed energy audits, benchmarking, or commissioning for your buildings, you do not need to start from scratch. For each of the technology strategies, knowing your baseline conditions will guide you on next steps, whether simple, intermediate, or advanced. To make sure you do not miss an opportunity to improve performance in your buildings, we recommend that you create plans for what to do when equipment fails. Early replacement can often make sense depending on your goals and the business case.

When decarbonizing your buildings, start by making your buildings energy efficient and then add on-site renewables. An efficient building generating its own power will have the flexibility to interact with the electric grid to maximize use of renewables in your community (e.g., by shedding or shifting load as part of a demand response program). To achieve zero carbon goals, your plan may also need to incorporate off-site renewables, renewable energy credits (RECs) and/or carbon offsets, but energy efficiency should be prioritized as the most cost-effective and impactful option.

Decarbonization Priority Waterfall



Learn more at betterbuildingssolutioncenter.energy.gov/

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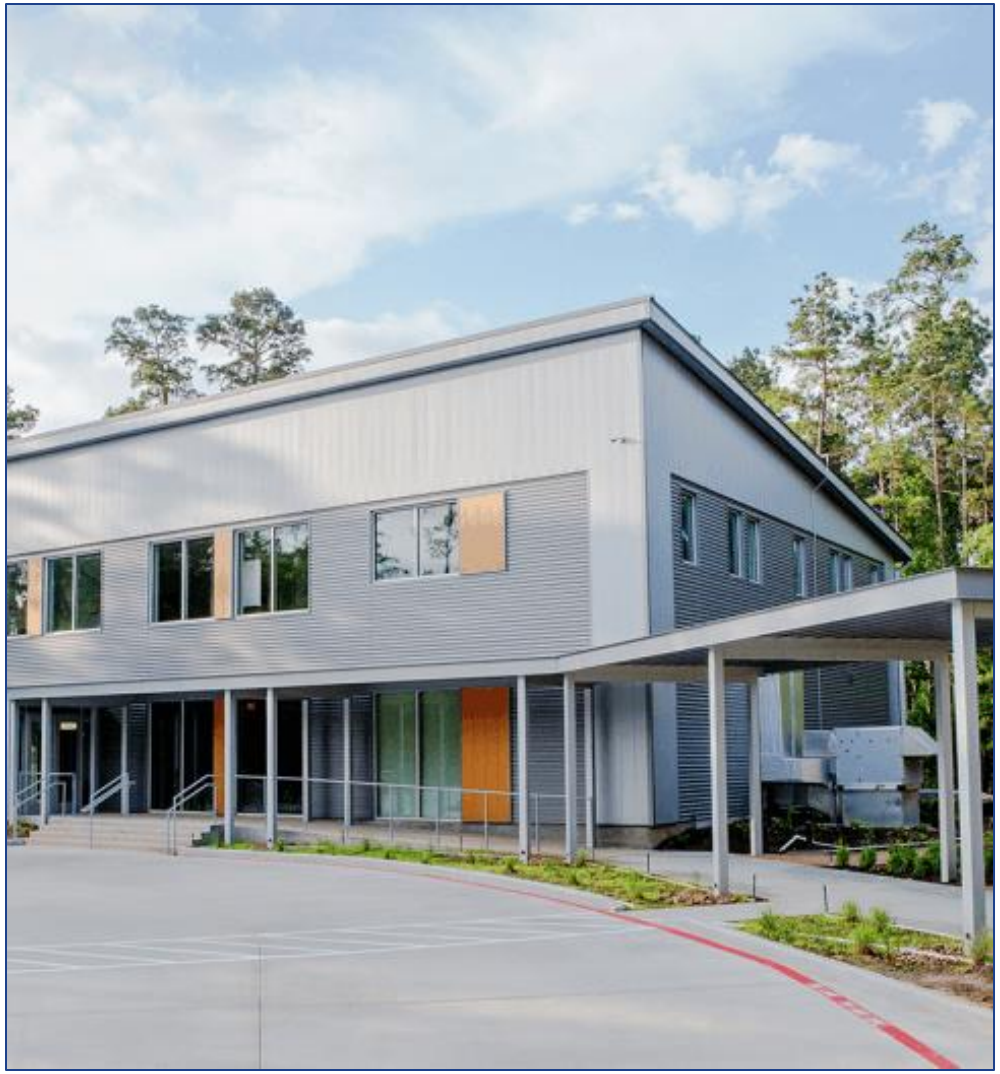
Published October 2021 | DOE/EE-2505

# Featured Resources

- **On-Demand PPL Webinars**
- Low Carbon Peer Exchange; Plug and Process Load Management for Low Carbon Strategy
- Community College of Allegheny County and Cornell University; No Purchase Necessary: Low to No Cost Plug Load Management Strategies
- Houston Advanced Research Center (featured at right); Getting to Net Zero Energy Through Strategic Building Operations and Plug Load Management



# NEW Fact Sheet Featuring Integrated Lighting Campaign Winner

- Minnesota Department of Transportation Cedar Truck Facility
- Winner: Integrated Controls for Plug Loads and Lighting Systems
- Fact sheet can be found under Case Studies on the PPL website

Photo Credit: Minnesota DOT

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Integrated Controls for Plug Loads and Lighting Systems

CASE STUDY: Minnesota DOT Cedar Avenue Truck Station

**About the Participant**

The Minnesota Department of Transportation (MnDOT) has more than 1,075 buildings with 137 truck station campuses across the state. MnDOT's Cedar Avenue truck station, located in Richfield, Minnesota, provides critical roadway snow removal support within the Minneapolis metro area. It includes administrative offices, a training room, and a large breakroom, along with truck maintenance and service facilities.

The focus of this case study is to highlight the strategies used at Cedar Avenue truck station for integrating plug load and lighting systems. An integrated controls pilot project with retrofit installation was conducted from October 2019 to April 2020 and has been recognized by the Integrated Lighting Campaign in the following categories:

- Integrated Controls for Plug Loads & Lighting Systems
- Integrated Controls for HVAC & Lighting Systems

The lighting-plug load integration project was co-funded by MnDOT, the U.S. Department of Energy, and Xcel Energy.

**Project Motivation**

The project included the retrofitting and integrating the solid-state networked lighting control with plug load, and HVAC (heating, ventilation, and air conditioning) system operation. Existing lighting fixtures in the office space were near the end of their life. The facilities team looked at this retrofit and integration effort as an energy savings project. This facility was a suitable candidate to achieve energy savings by implementing occupancy-based control and lighting integration because of its continuous operation and highly variable occupancy pattern.

**Plug Load + Lighting System Integration**

Each of the new luminaires has an occupancy sensor, light level sensor, and wireless communication capabilities. The occupancy sensors in the virtually created lighting zones manage the lighting system operation. The plug load control module operates controlled outlets based on the wireless signal from the occupancy sensors. All faceplates of the controlled outlets have a button for manual override by the user. The signal flow is unidirectional—from the lighting occupancy sensor to the plug load controller. The plug load control module cannot operate the lighting fixtures.

Cedar Avenue truck station
*Photo from Mark Moehlenbrock, MnDOT*

**Participant Quick Facts**

- Building Details
  - Location: Richfield, MN
  - Office area: 11,300 sq.ft.
  - Total building size: 74,776 sq.ft.
  - Office usage: 24/7 operational facility with highly variable occupancy pattern
- Controlled Plug Load Details
  - Dual controlled outlets: 4
  - Half controlled outlets: 5
  - Transmitters: 4
  - Cubicle controls: 2
- Loads Connected to Controlled Outlets
  - Computer monitors
  - Desk fans
  - Miscellaneous office equipment

**About Automatic Receptacle Controls (ARCs)**

- ARCs turn off power to receptacle plugs using occupancy sensors, control schedules, or timers
- Available in single or duplex outlet control configurations
- Plug load controllers can communicate to the outlets through wires or wirelessly
- Also known as controlled receptacles or controlled outlets

Learn more at betterbuildingssolutioncenter.energy.gov

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# PPL Team Updates: Project Highlights

## Automatic Receptacle Controls

- Working on strategies for increased market uptake

Control marked receptacle

Wireless controlled receptacle

Source: BBA TRT Webinar 4/30/20 - Harold Jepsen

## Energy Efficiency in Medical Imaging Equipment

- Supporting DOE efforts

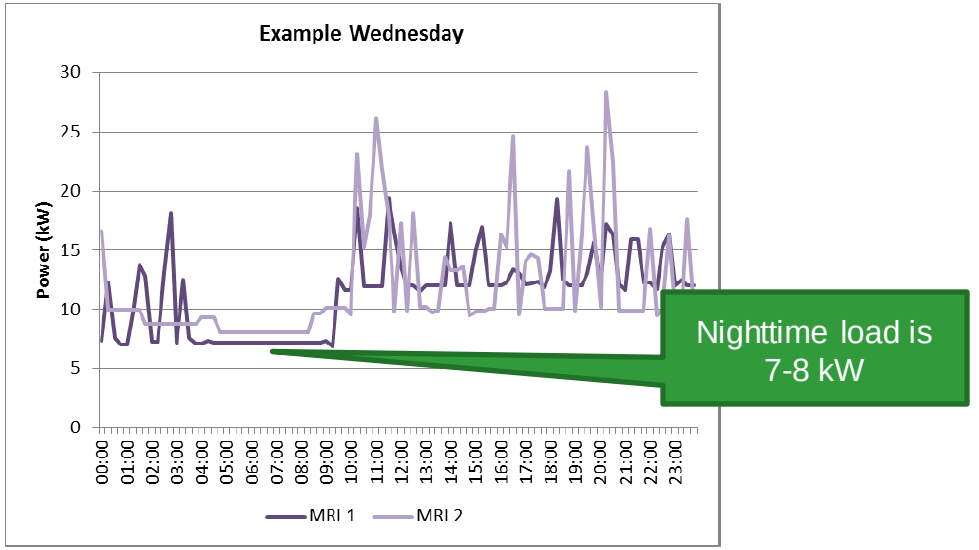


**Figure 4-8** **MRI 15-minute load profiles for an example weekday (Wednesday)**

Source: M. Sheppy, S. Pless, and F. Kung, "Healthcare Energy End-Use Monitoring," 2014.

# Contact us

Team Inbox:

**PPL@NREL.gov**

Website:

**https://betterbuildingsinitiative.energy.gov/alliance/technology-solution/plug-process-loads**

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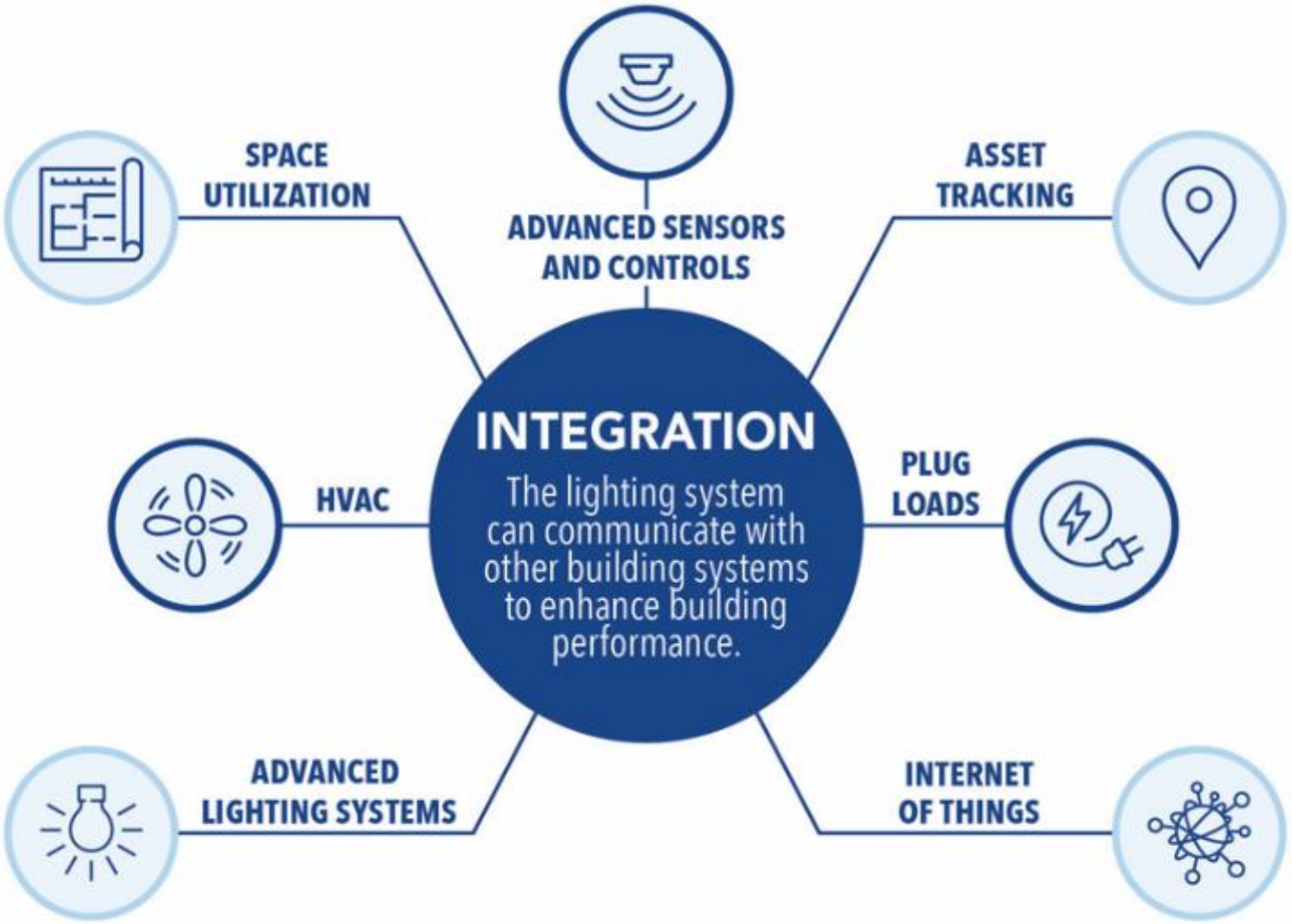
# Integrated Lighting Campaign

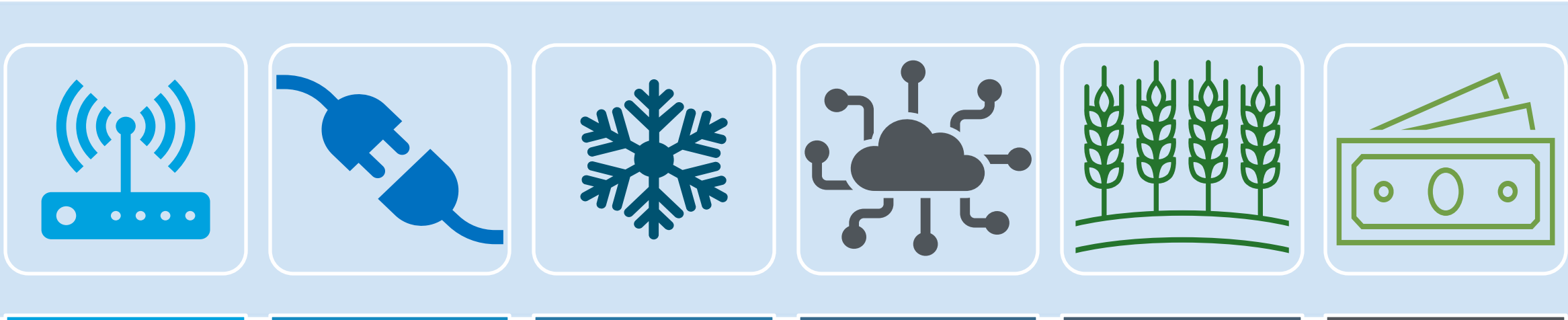

**Axel Pearson**

Pacific Northwest National Laboratory

# Integrated Lighting Campaign - The Focus



# 2022 Recognition Categories for Participants



- Advanced Use of Sensors and Controls for Lighting
- Integrated Controls for Plug Loads and Lighting Systems
- Integrated Controls for HVAC and Lighting Systems
- Other Integrated Systems and Lighting
- Integrated Lighting and Horticultural Controls — New in 2022!
- Innovative Maintenance, Operation, and Financing Service Models — New in 2022!

# CASE STUDY: Advanced Use of Sensors and Controls for Lighting

Bryan MEDICAL CENTER

Project Details:

- 3 million ft² building portfolio across two campuses in Lincoln, NE
- Empowered office workers set their own light levels in their workspace
- Reduced lighting-related calls to helpdesk
- 57% energy savings

A view of the control dashboard for the second floor of the East Campus.

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Healthcare Campus Recognized for Innovative Use of Lighting Sensors and Controls

CASE STUDY: BRYAN HEALTH

**About the Project**

Bryan Health is a locally owned, nonprofit healthcare organization serving patients in Nebraska, as well as parts of Kansas, Iowa, South Dakota, and other states in the region. When a scheduled remodel neared, Bryan Health saw an opportunity to upgrade lighting throughout its East and West Campus locations in Nebraska and replace all their fluorescent luminaires with energy-efficient LEDs. A new, modern lighting system held the promise of significantly reducing energy consumption, lowering operating costs, and streamlining maintenance. But what else could it do? It turns out, quite a lot.

Mike Wiruth, master electrician at Bryan Health, explored lighting applications and integration strategies with internal stakeholders that could also support physician productivity and contribute to patient wellness and healing.

**Project Goals**

- **PERSONALIZATION.** Give office personnel and medical health providers ability to set their own task lighting scenes. Lighting control is particularly important for radiologists when taking x-rays and reviewing scans.
- **DIMMABILITY.** Lighting fixtures needed to be dimmable to benefit from daylight harvesting but also to reduce brightness of the LED lights to reduce glare.
- **EFFICIENCY.** They needed a lighting system that could streamline and automate certain tasks, reduce unnecessary energy consumption, and lower utility bills. As an added bonus, their utility, Lincoln Electric System, offered Bryan Health a rebate for each fluorescent lamp removed and a separate rebate to cover a percentage of labor costs for installing new controls.
- **CENTRALIZATION.** They also wanted to manage it all from an easy-to-use, cloud-based, centralized lighting system with advanced data visualization.

Bryan Medical Center in Lincoln, NE

**PROJECT QUICK FACTS**

- Bryan Health owns three million square feet of building space in Lincoln, Nebraska, which includes two acute care facilities and many outpatient clinics.
- Bryan Health partnered with lighting integration firm AES Design to purchase the fixtures and the lighting management system.
- Architectural firm Davis Design was contracted to specify future work to meet new campus standards and develop as-built documentation for all ongoing work.

**KEY STRATEGIES AND OUTCOMES**

- Bryan Health employed the following **advanced lighting strategies**:
  - Lighting management system
  - Occupancy sensors
  - Task tuning levels and preset lighting scenes
  - Remote-controlled switches
- Advanced lighting and integration strategies led to the following positive **outcomes** for Bryan Health:
  - improved energy efficiency
  - better diagnostics
  - fewer support calls
  - shorter response times
  - increased individual comfort
  - remote control
  - reduced lighting energy use by 57%

Learn more at betterbuildingssolutioncenter.energy.gov/

ENERGY

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Case Study Published Here!

U.S. DEPARTMENT OF ENERGY

# Submit for Recognition by ~~March 30~~ April 15th!

## Program Description

Narrative:

Description of Program including start/end dates – please include pilot demonstrations if applicable, or Description of Contributions to the Integrated Lighting Campaign

Supporting Data:

(e.g., number of buildings/systems impacted, energy savings measured, Participants/projects recruited to the ILC, etc.)

# More questions?


… or IntegratedLighting@pnnl.gov

# Technical Presentations

# Mark Moehlenbrock, PE

Minnesota Department of Transportation

# Plug Load Control Integration at Minnesota Department of Transportation

Mark Moehlenbrock, PE, MnDOT Energy Engineer

# Minnesota Department of Transportation Buildings

Over 1075 Buildings and 6,000,000 Square Feet

18 Regional Headquarters Campuses

137 Truck Station Campuses

68 Rest Areas

# Cedar Avenue Truck Station

75,000 Sq Ft Maintenance Facility

11,000 Sq Ft “Office Area”

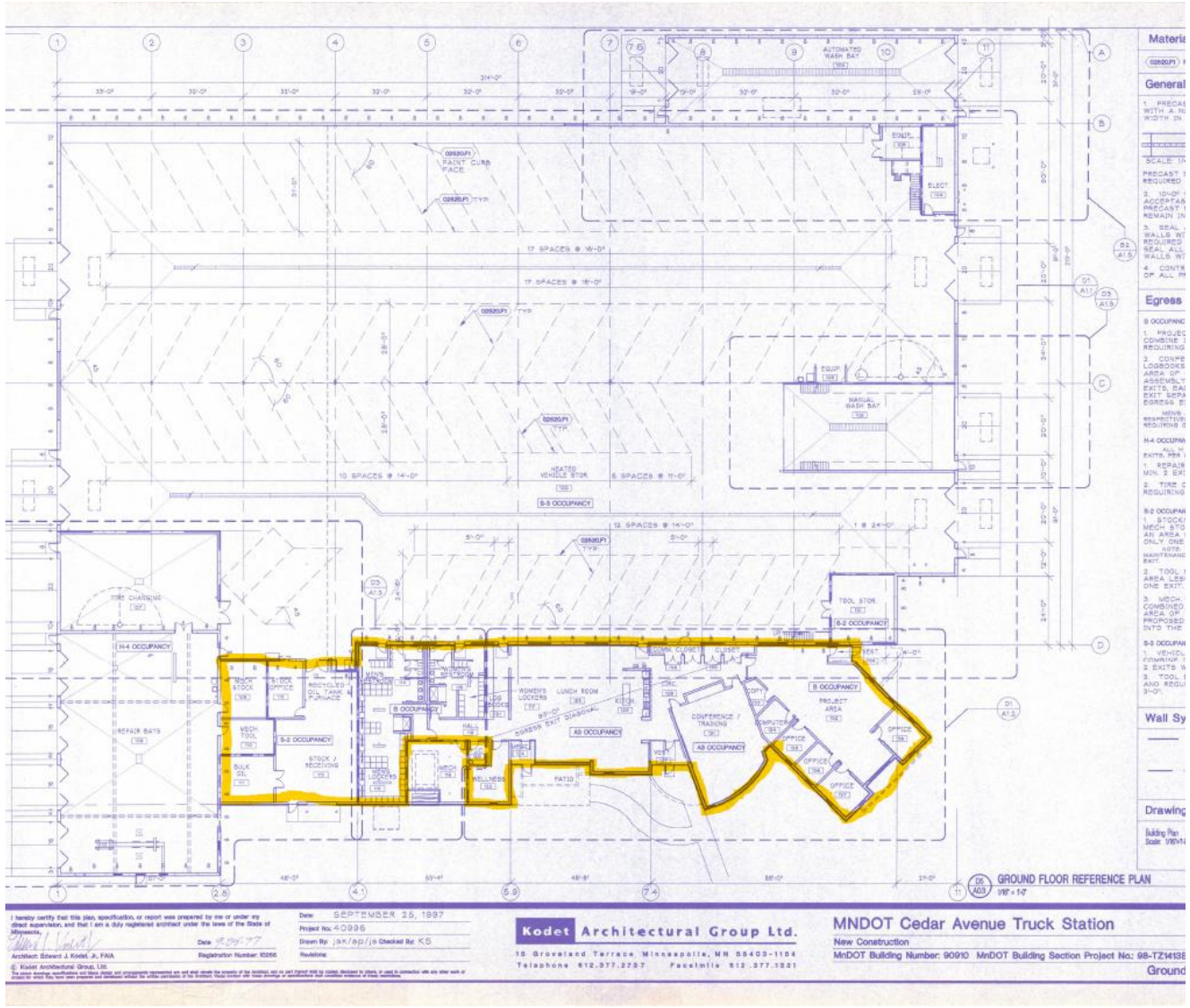
- Offices/Cubes
- Lunch/Break Room
- Storage Rooms
- Restrooms/Locker Rooms

# Cedar Avenue Truck Station

Vehicle storage area and repair bays had previously received high-bay LED Upgrade

Office area existing lighting was mostly 4-lamp linear fluorescent fixtures and recessed fluorescent can-lights (circa 1996).

Building occupancy is highly variable—HVAC scheduled 24/7



# Integrated Lighting Retrofit Project

- Slipstream was the driver behind the project
  - Received grant funding from DOE for integrated lighting retrofit pilot projects
  - Worked with Xcel Energy to find project sites and rebate opportunities
  - Worked with Cree Lighting and Legrand for lighting and plug load products
  - Worked with partners to provide lighting, HVAC integration, and plug load integration designs
  - Worked with PNNL for pre/post project M&V

Information Sheet

Minnesota/Colorado/New Mexico

Xcel Energy®
RESPONSIBLE BY NATURE®

## Opportunity to Participate:

**Seventhwave's Integrated Controls Retrofit Pilot – a holistic approach to drive greater energy savings**

In 2018, Seventhwave, an independent, nonprofit energy consulting firm will be offering an Integrated Controls Retrofit pilot in some of Xcel Energy's service territories. Funded by the U.S. Department of Energy (DOE), the pilot is designed to help commercial businesses take a holistic approach towards making energy-efficient lighting upgrades.

A total of four to five sites will be selected into the pilot, and businesses which meet the pilot's criteria have an opportunity to obtain the retrofit funding and benefits below.

### Seventhwave Pilot Overview:

**Purpose:**
Encourage a deeper, holistic approach to interior, energy-efficient retrofit projects. Pilot sites will be retrofitted with LED fixtures which have embedded controls capable of connecting to additional systems such as HVAC terminal units to drive increased energy savings.

**Products tested:**
Participating sites will receive a complete lighting retrofit along with the associated control system.

**Benefits:**
- Receive grant funding to offset retrofit costs
- Gain first-hand knowledge of cutting-edge products
- Potential national publicity for your business through DOE case studies and other media
- Free project measurement and verification including energy savings, occupant satisfaction, cost effectiveness and maintenance

**Site requirements to participate:**
- Offices, outpatient healthcare facilities or public spaces
- Existing lighting should be typical fluorescent fixtures
- Spaces should have some amount of daylighting
- Direct digital control of HVAC units
- Sites sized from 3 to 10k square feet (either standalone or within a building)

**What's Xcel Energy's role in the pilot?**
Xcel Energy will offer rebates to pilot participants through our Custom Efficiency program to further offset the costs of equipment installed. Based on the results of the pilot, we may develop a standardized new rebate product offering for this emerging technology to our commercial customers.

**Want to learn more?**
If you're interested in participating, please contact a project representative at Seventhwave for more information:


**Scott Hackel**
*Director of Engineering, Seventhwave*
608.210.7129
SHackel@seventhwave.org

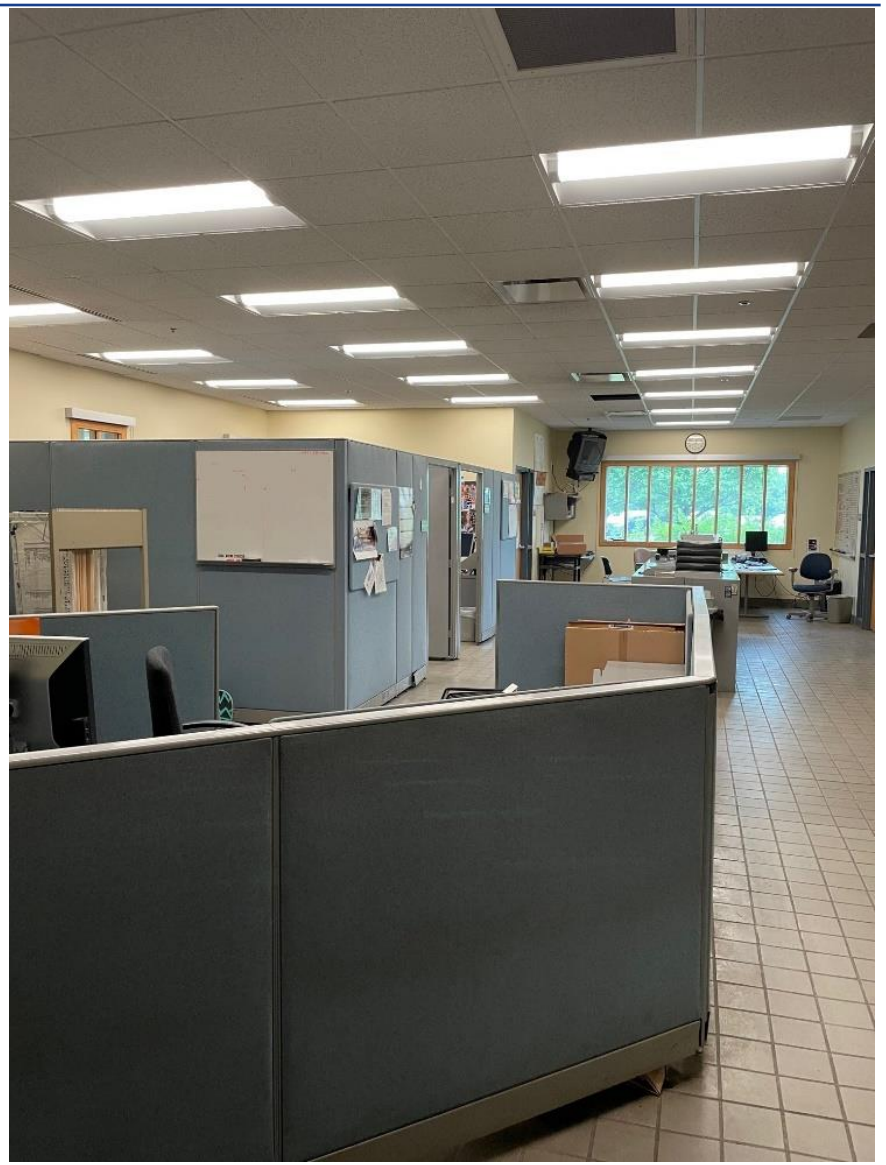
**Jacqueline Freidel**
*Project Manager, Seventhwave*
608.210.7141
JFreidel@seventhwave.org

# Integrated Lighting Retrofit Project

- MnDOT Cedar Avenue truck station was an excellent candidate:
  - Desire to save energy
  - Fit into square footage range required of Slipstream
  - Had fluorescent fixtures near the end of their life
  - Had existing BACnet HVAC controls
  - Highly variable occupancy to make the most of occupancy detection

# Integrated Lighting Retrofit Project

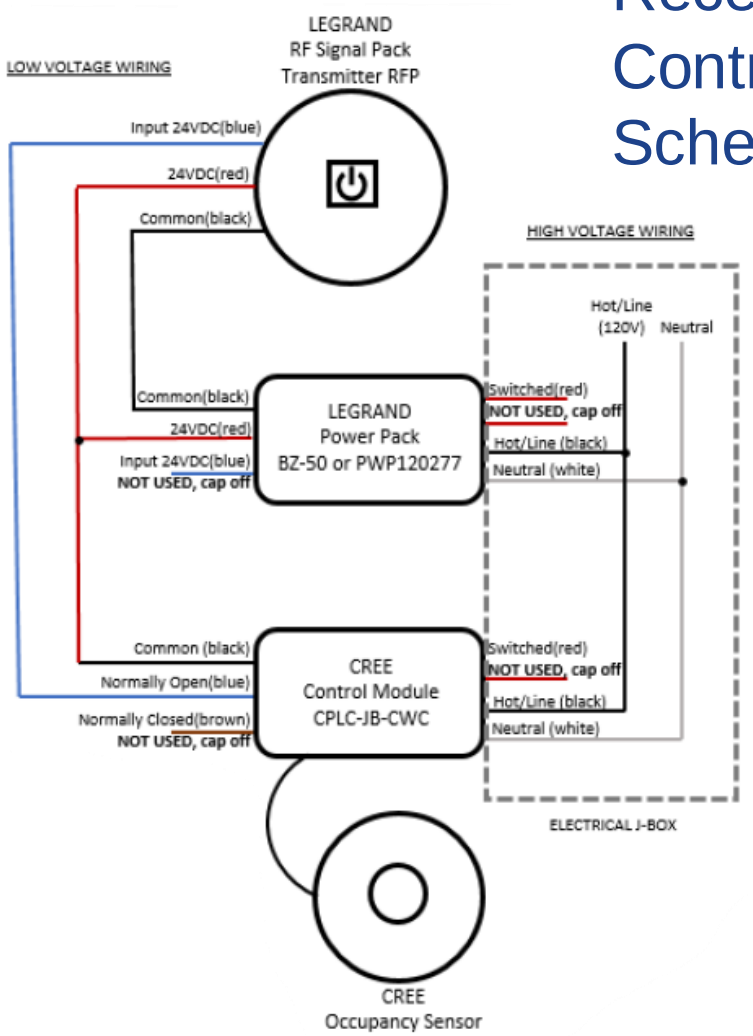
- Cree “SmartCast” LED luminaires with occupancy detection
- Lighting network zones
  - Each luminaire has an occupancy sensor, light level sensor, and wireless communication.
  - Virtual zones created with wireless configuration tool.
  - Occupancy in lighting zone (individual room) triggers lights
  - Controlled receptacles tied to lighting zone through Cree SmartCast wireless plug load control module.
  - HVAC zones created through “Gateways” to BACnet automation system. Occupancy in HVAC zone (room or group of rooms served by 1 terminal unit) triggers HVAC occupancy signal



# Hardware

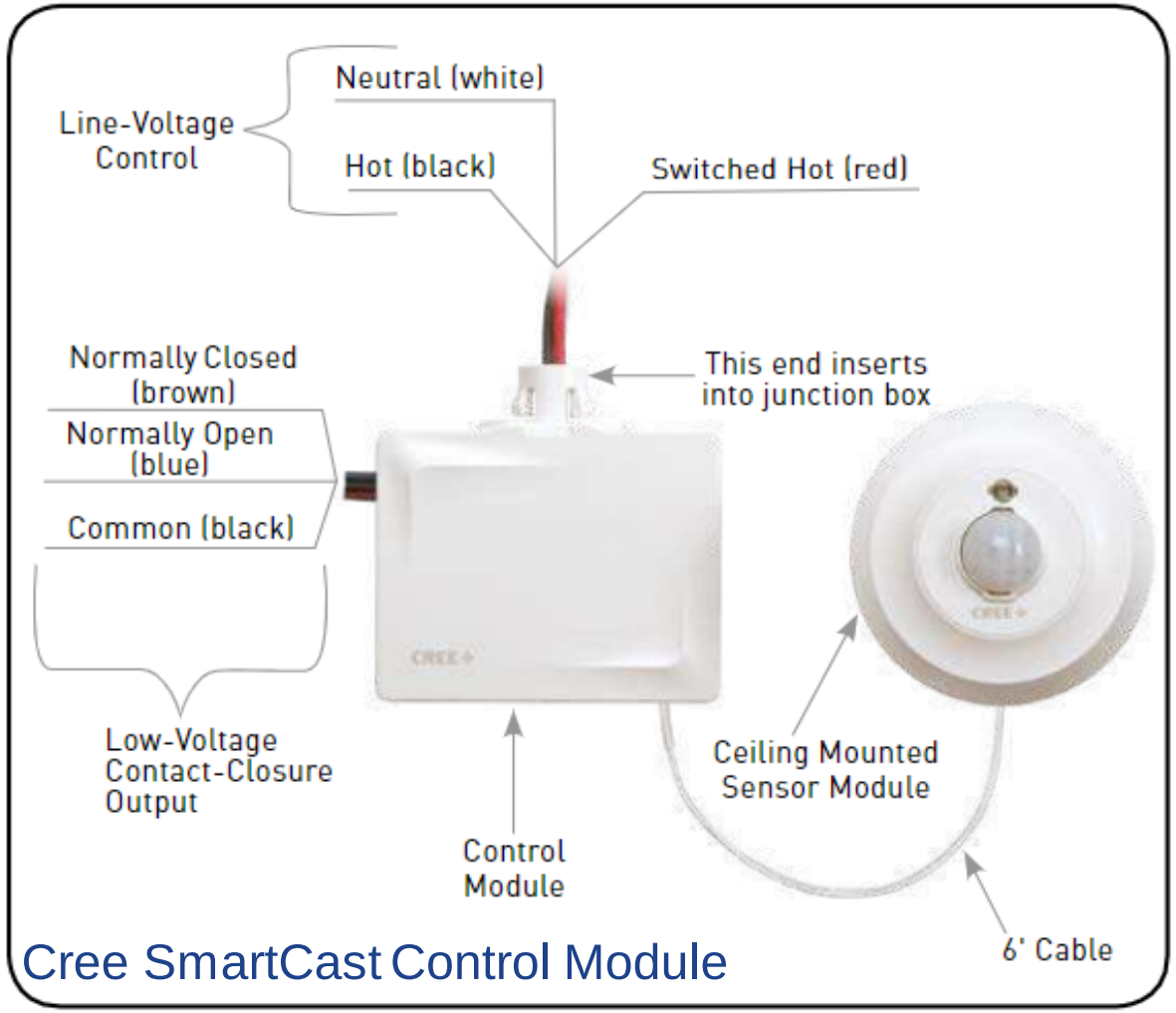
## Cree SmartCast Configuration Tool


## Receptacle Control Schematic



# Hardware

Legrand Controllable Receptacle and Wireless Transmitter




Cree SmartCast Control Module

# Hardware Installation

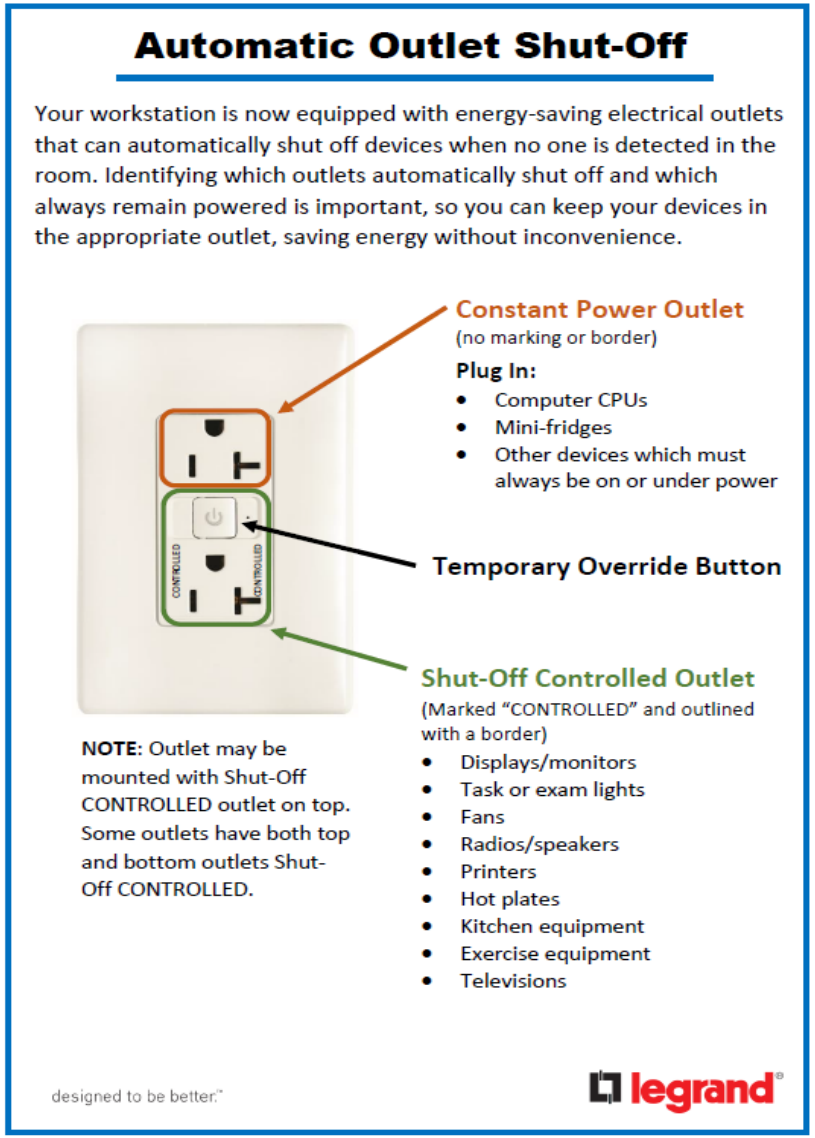
- Controllable receptacles installed concurrently with lighting
- Buttons on Legrand controllable receptacles and RF transmitters were used to “bind” the receptacle to transmitter
- SmartCast control module relay wired to RF transmitter
- SmartCast control module included in room’s lighting occupancy zone.

# Commissioning

- Tested binding between RF transmitters and receptacles
- Tested occupancy detection
- Verified the equipment was plugged into correct receptacles (controlled vs uncontrolled)
- Verified that power turned on and off at receptacle

# User Engagement

- Building occupants kept in loop during construction
- Sent controllable receptacle user guide to supervisors
- Return visits to the site resulted in opportunities to find out about problems and address them (e.g. occupancy zone for TV was too small, etc.)



## Automatic Outlet Shut-Off

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
- 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.

designed to be better.™

legrand®

# Energy Savings

- Annual energy saved with retrofitted luminaires: 19,036 kWh
- Total controlled outlets: 13
- Annual plug load energy saved in controlled outlets: 774 kWh
- Plug load material cost: $1,654
- Plug load labor cost: $556

# Best Practices

- Choose controlled equipment wisely and don't overreach
  - Computer monitors, desk fans, miscellaneous office equipment work well
  - Be careful with TVs and AV equipment and make sure occupancy zone is large enough to capture all users
  - Vending machine was a failure—takes time to reboot, and hangry people don't want to wait for their candy bars
- Keep open communication with building occupants so that initial problems can be solved quickly before disillusionment sets in
- Make sure electricians understand the scope, including commissioning.
- If lighting network is connected to other building networks, make sure IT is involved early and during the commissioning process

**Dr. Jan Kleissl**

University of California San Diego

**Keaton Chia**

University of California San Diego

# SMART PLUG Load Controls Integrated with a BUILDING ENERGY MANAGEMENT SYSTEM

# UCSD TEAM

Prof. Jan Kleissl
*Director, CER*
*Professor, MAE*

Jesse Wolf
*Computer Science*
*Senior*

Aakshi Kochhar
*Cognitive Science*
*Senior*

Sayan Shaw
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*MAE*

Xiaohan Fu
*Computer Science*
*Masters Student*

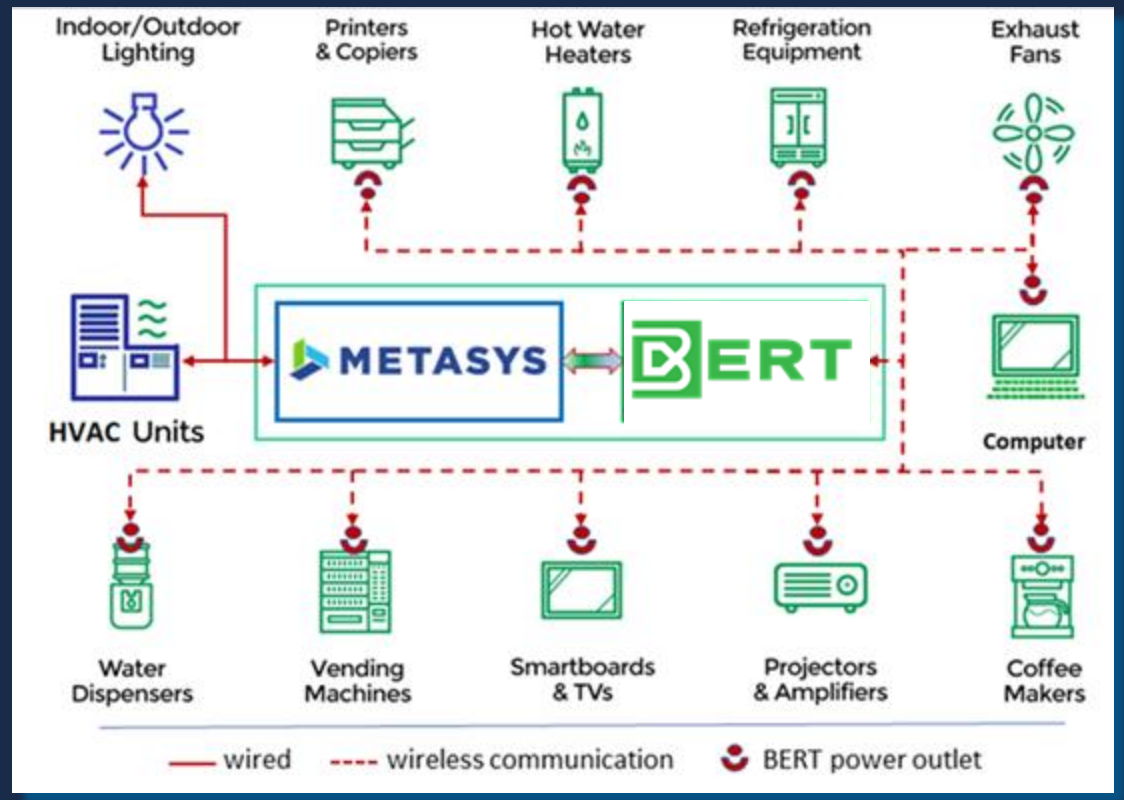
Mandy Lee
*Data Science*
*Junior*

Vardhan Agarwal
*Computer Science*
*Junior*

Leo Duga
*Mechanical Engineering*
*Senior*

# PROJECT

California Energy Commission (CEC) grant to demonstrate the added value of integrating plug load controllers into a building energy management system



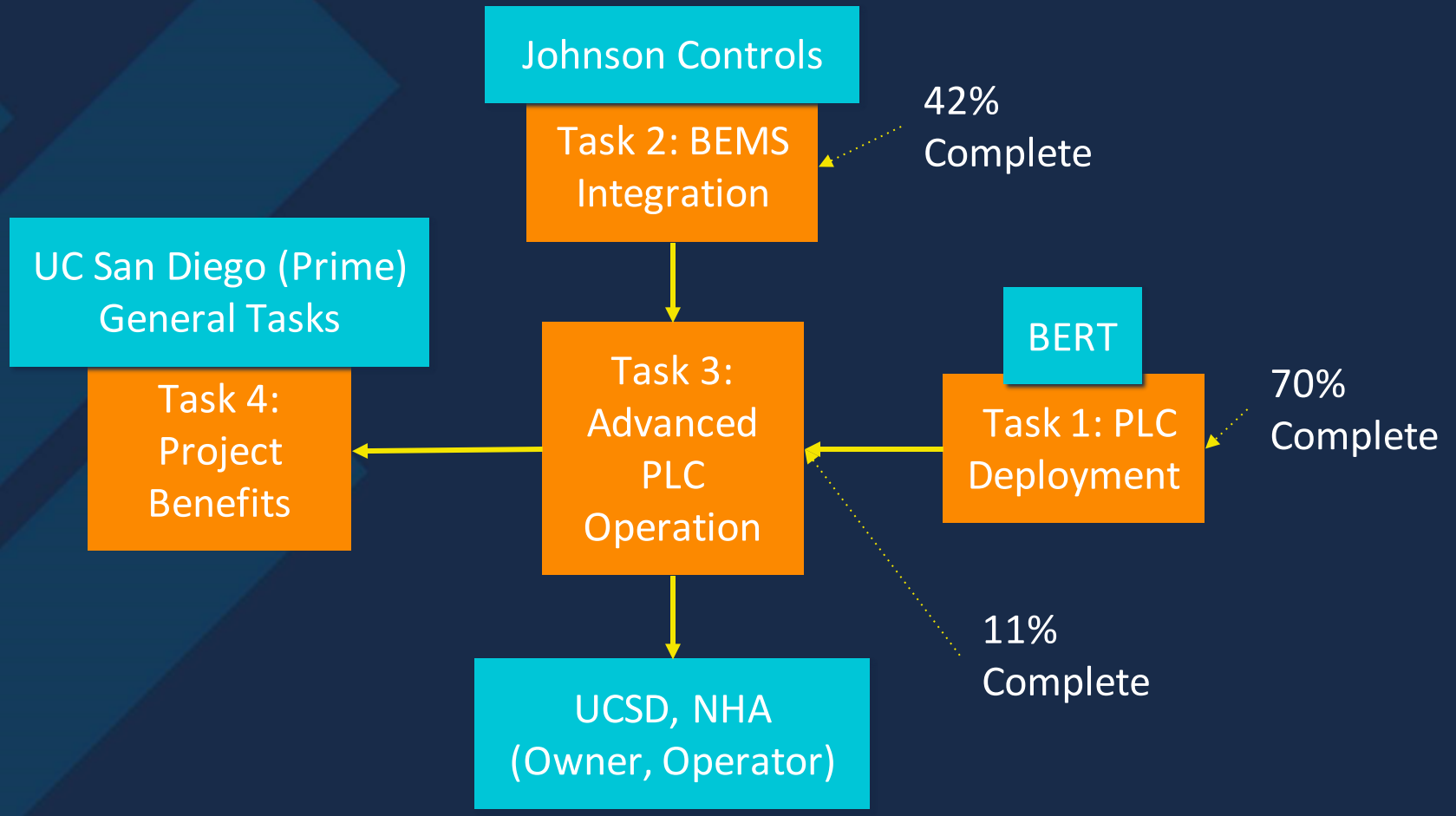
# POTENTIAL BENEFITS

- Ease of use - single user interface for all integrated systems
- Extended reach of building energy management system (BEMS) (distributed AC units)
- Sharing of data between systems
- Greater energy savings & peak demand shaving
- Insights into energy consumption & space usage
- Identify redundant equipment, equipment degradation, and power anomalies

# OBJECTIVES

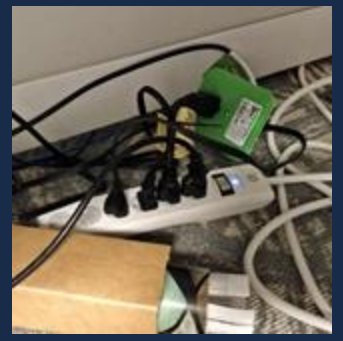
- Reduction of 20% in total building plug load energy use [CEC requirement]
- Instrument at least 9 buildings of 100,000 square feet or more [UCSD goal]
- Simple payback of less than five years from savings in energy and electrical load when compared to no controls [UCSD goal]
- Automated configuration and reconfiguration of plug load controllers (PLC) [UCSD goal]

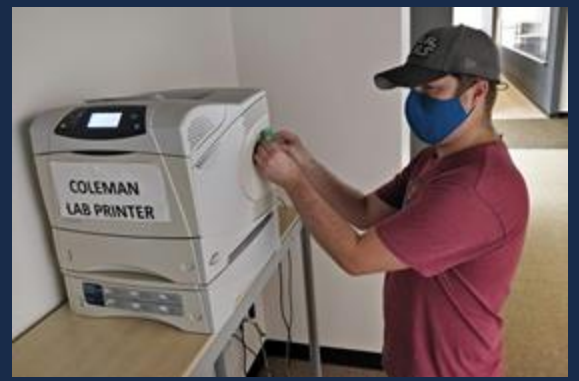
# COLLABORATION



# TASK 1 PLC DEPLOYMENT

- Building Selection
- Survey of plug loads
- Department approvals & scheduling
- Installation
  - MAC registration
  - Contact, wall & cord stickers
  - Short extension cords
  - Server connection verified
  - Install workbook
  - Track location, load, occupant
  - PLC renamed
  - COVID challenges




# PLUG LOAD CONTROLLER


- Wifi
- On/Off
- Metering
- Scheduling
- Power Threshold
- Temperature
- Interfacing
  - BertBrain
  - BACnet
  - API

# DEPLOYMENT

**14 Buildings** on the UCSD campus

**59 Departments** ranging from Enrollment and Anthropology to Athletics, Medical Education, and Computer Science

# DEPLOYMENT

## 744 Plug Load Controllers Installed

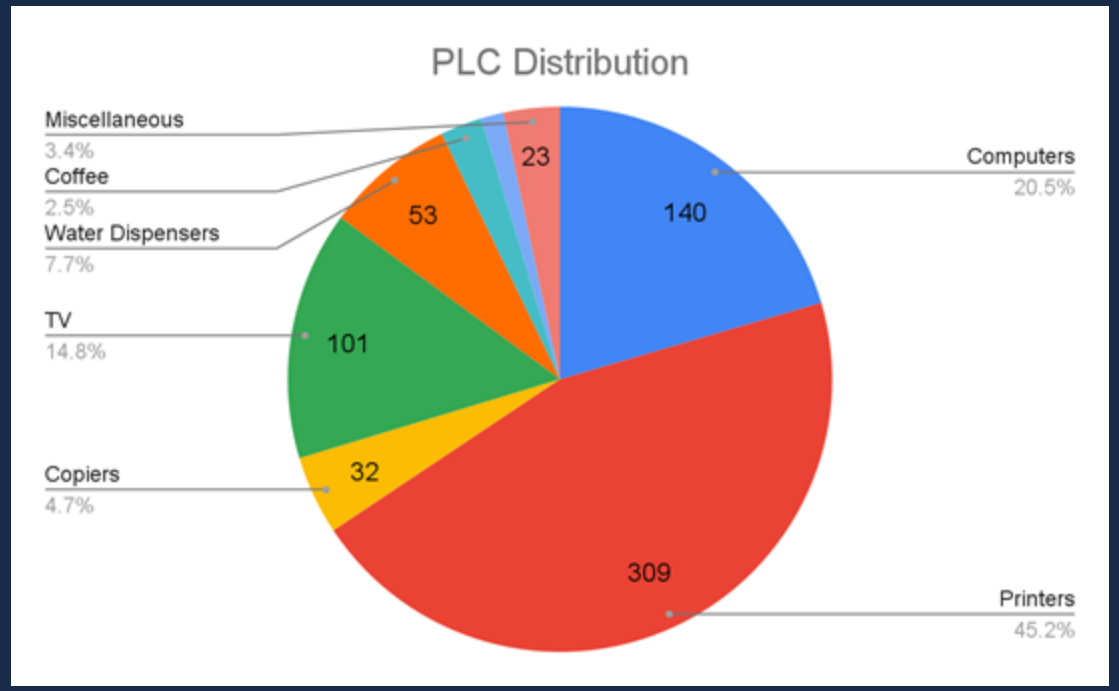
with a final goal of 1,000+

## 140 Computers

monitoring energy consumption only

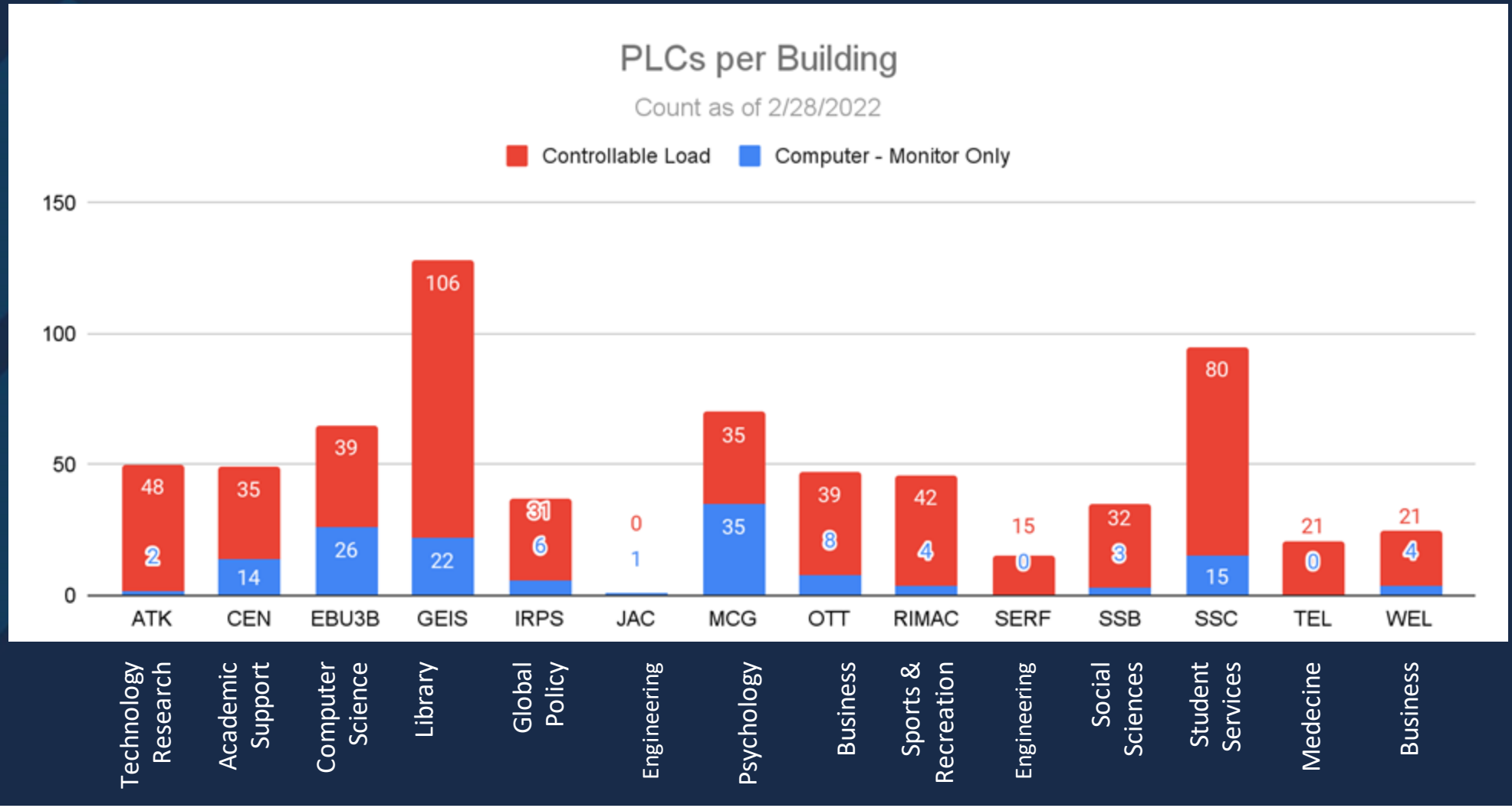
## 604 Controllable Loads

ranging from printers to tvs and keurigs



# DISTRIBUTION

- Majority of PLCs located in offices or open office settings
- Minority in classrooms and conference rooms



# TASK 2 BEMS INTEGRATION


PLUG LOAD CONTROLLER

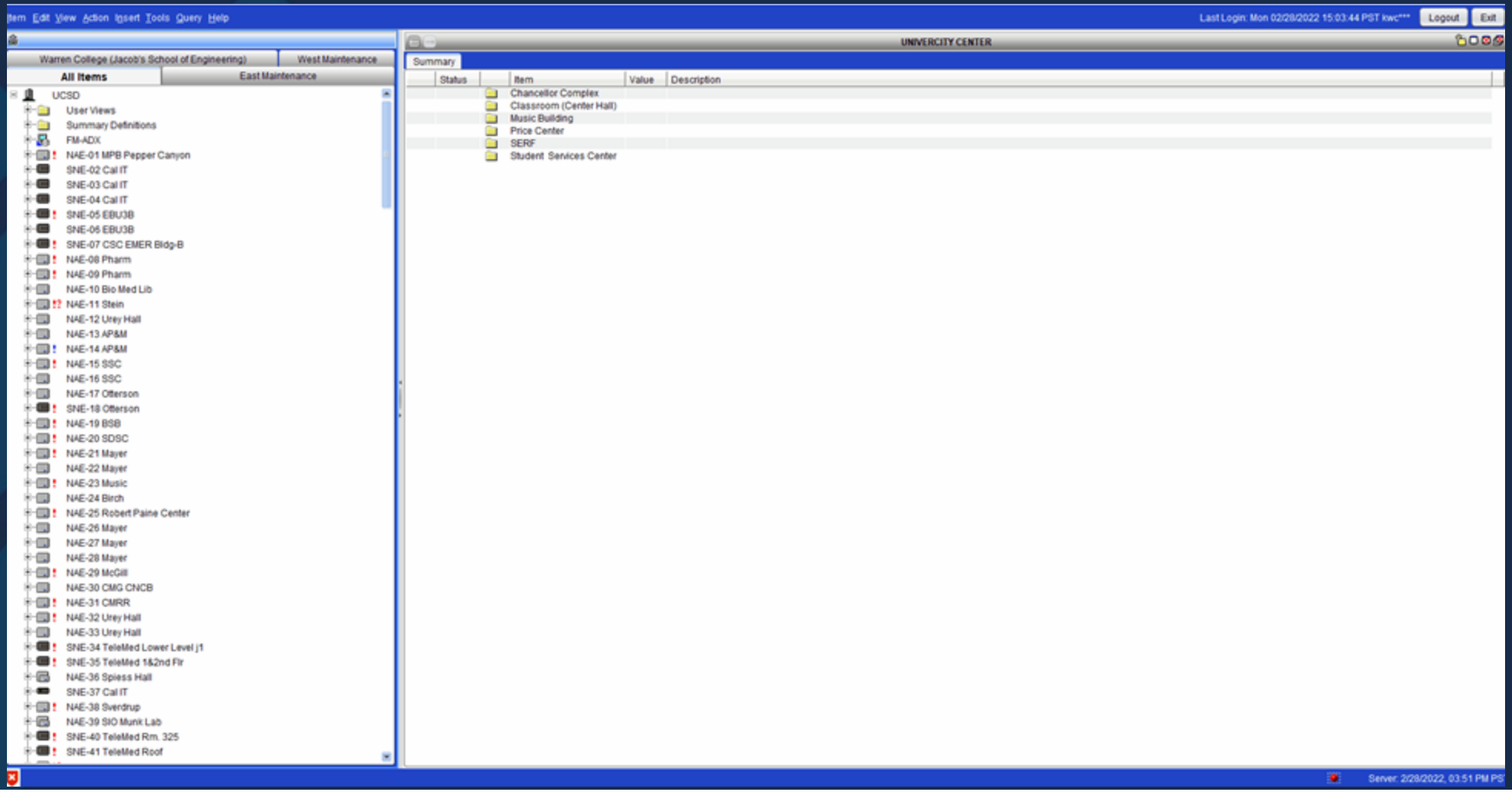
UCSD DEVICE NETWORK

BERT BACNET GATEWAY

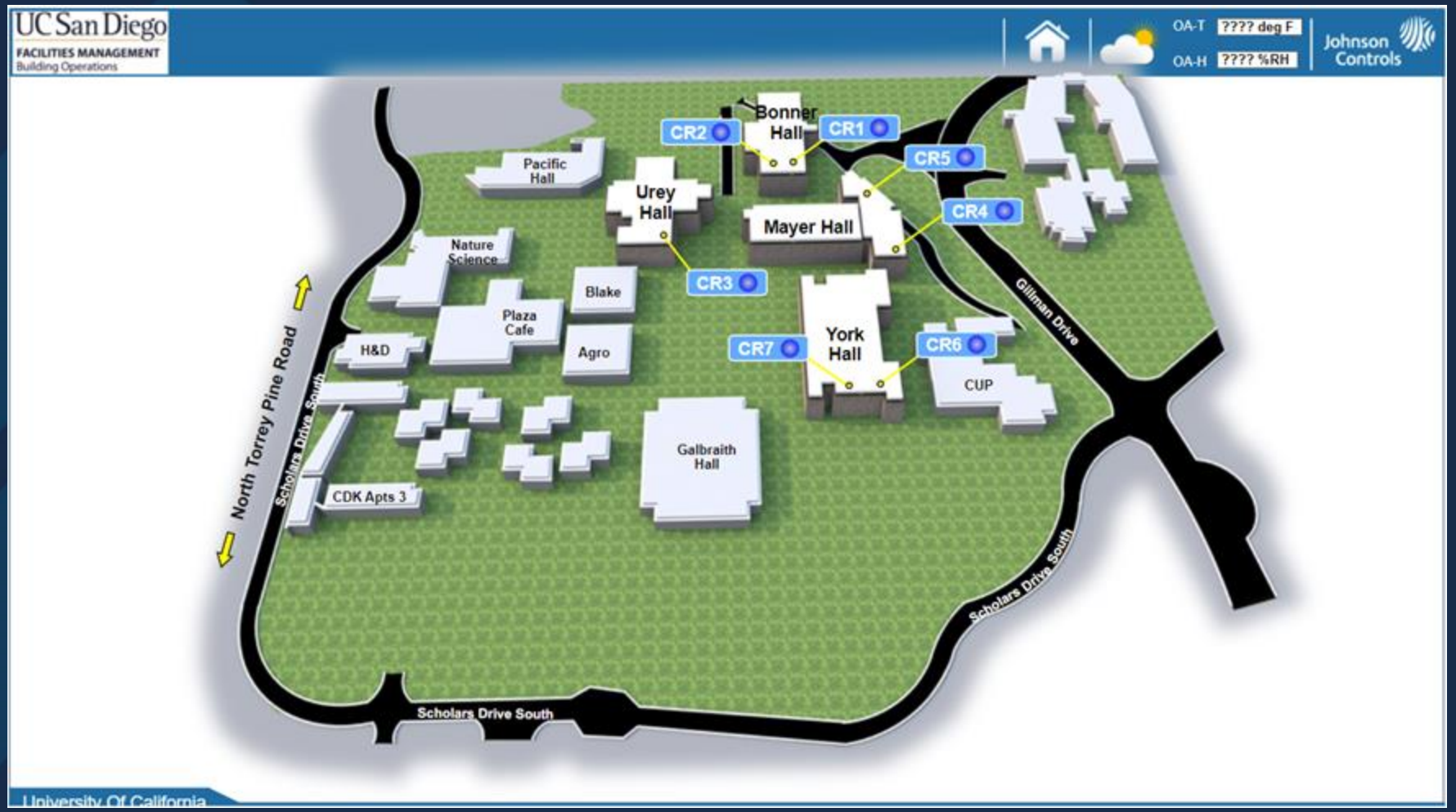
JCI VIRTUAL NAE (Network Automation Engine)

BEMS (Metasys Server)

# METASYS TOUR | Site Manager

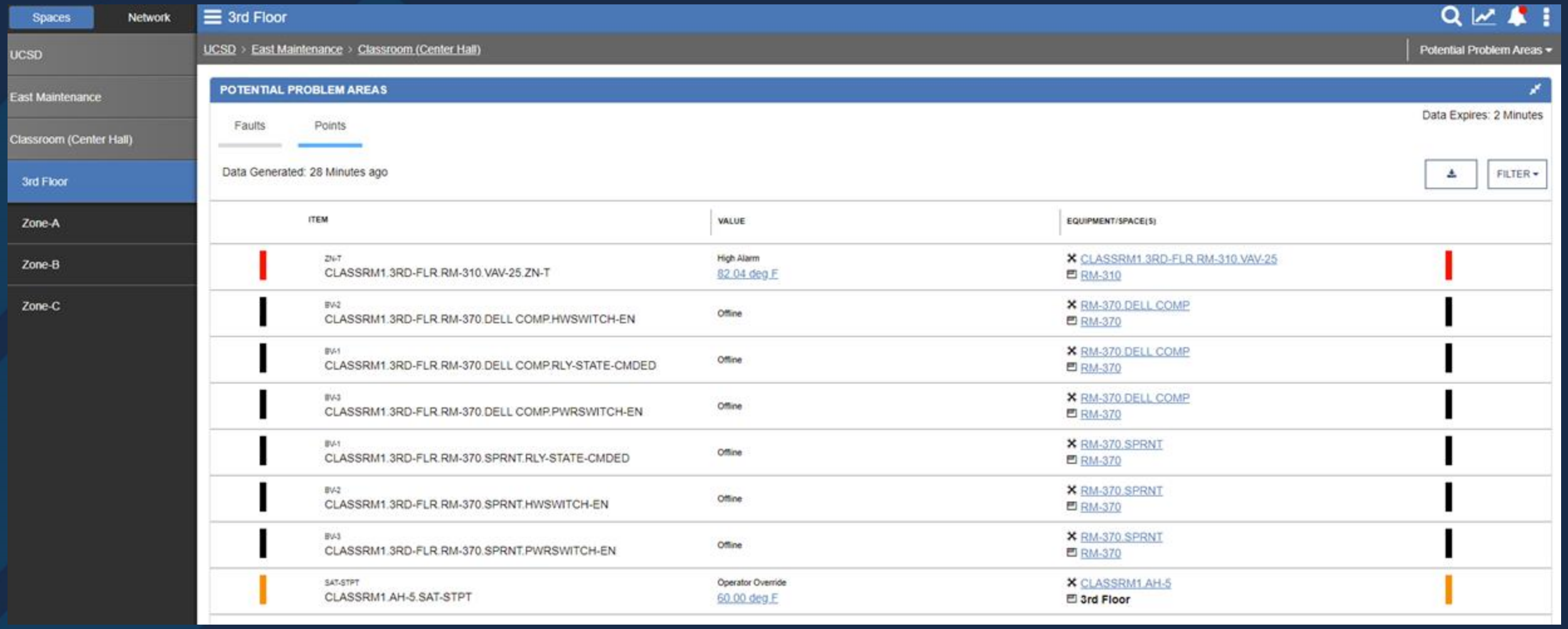


# METASYS TOUR | Campus UI



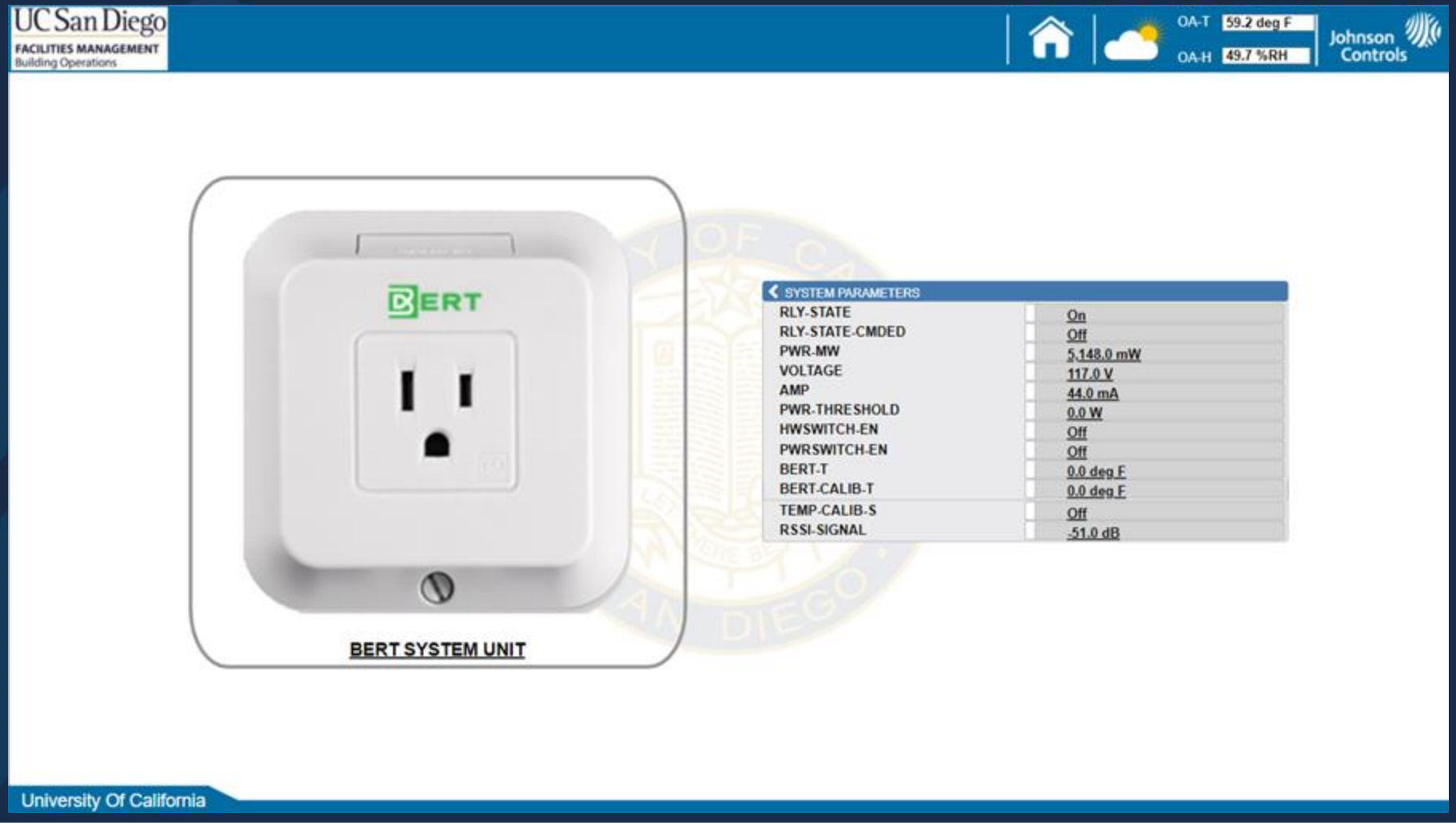
# METASYS TOUR | Building

# METASYS TOUR | Faults

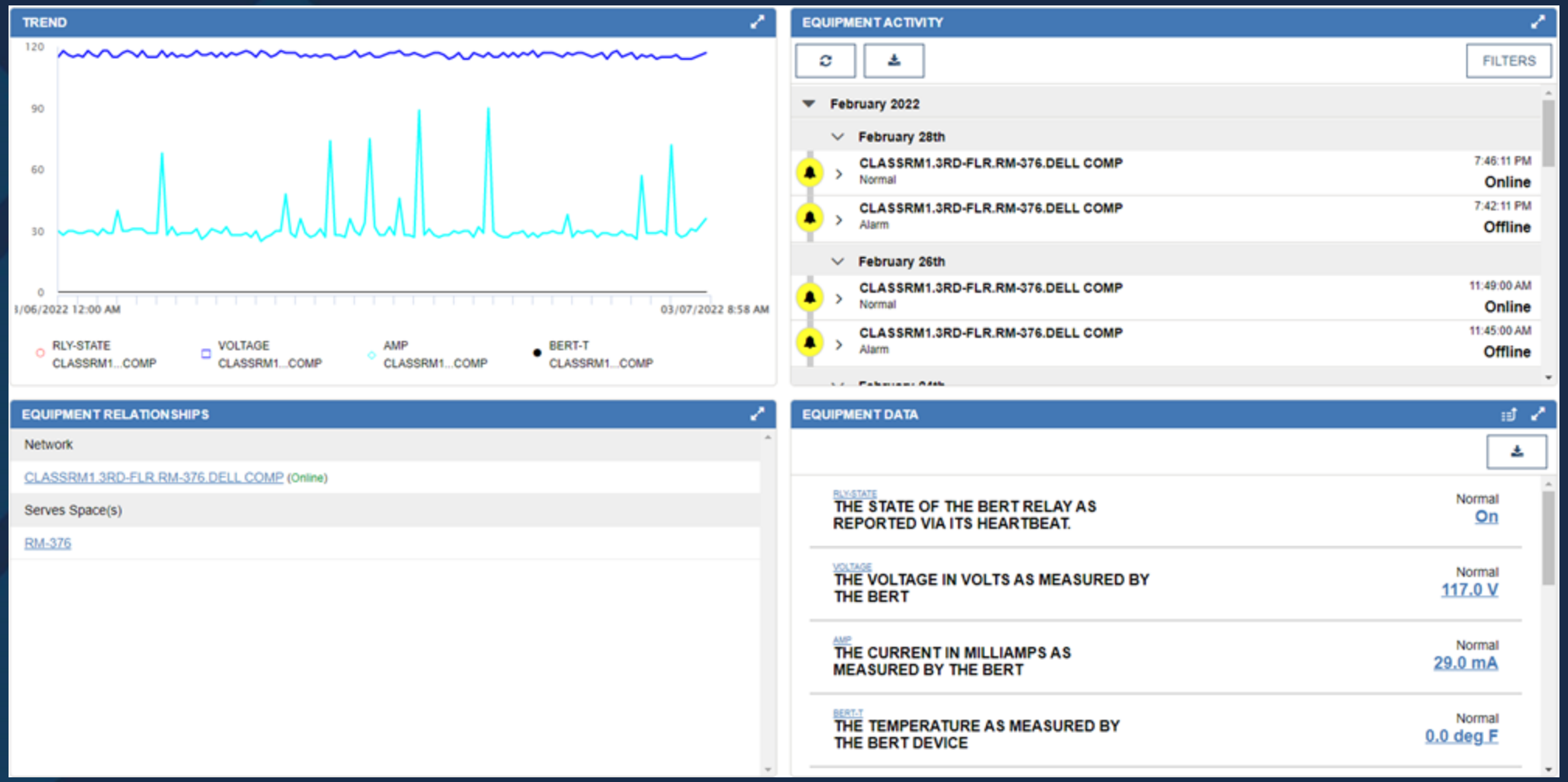


# METASYS TOUR | Floorplan

# METASYS TOUR | PLC



# METASYS TOUR | Details



# BASIC SCHEDULING

- Baseline 3 months data
- Use BEMS schedules to actuate PLCs for 3 weeks during summer and fall quarters

# TASK 3 ADVANCED PLC OPERATION

- Improve management process
- Implement advanced PLC strategies

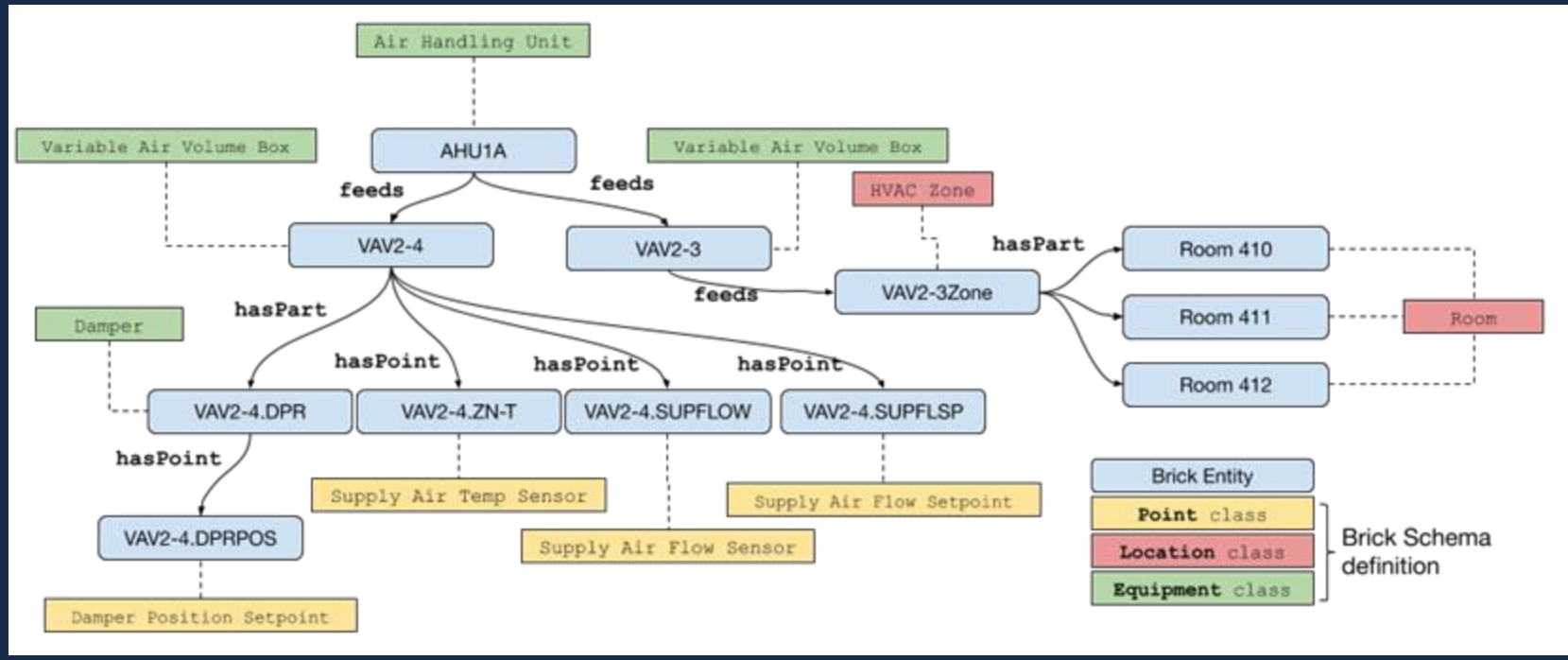
# MANAGEMENT

## PAIN POINTS - Dealing with dynamic system

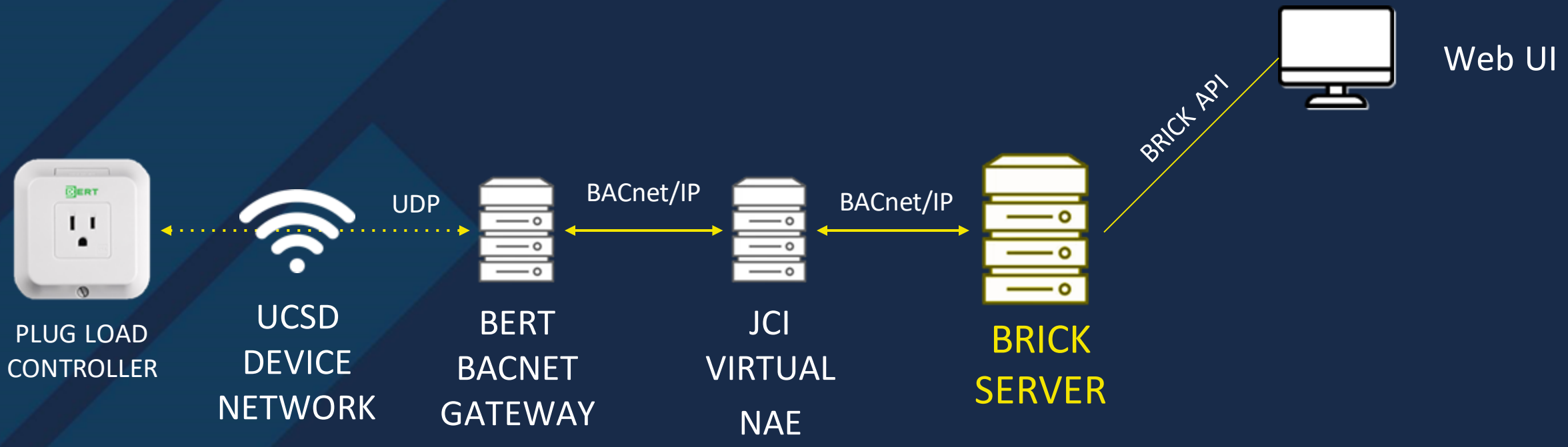
- Attached plug loads get changed
- Occupants move to different spaces
- New plug loads are added and others are removed
- PLCs are unplugged
- Occupant issues (power not on when needed)

# BRICK | A uniform metadata schema for buildings

BRICK is an open-source effort to standardize semantic descriptions of the physical, logical and virtual assets in buildings and the relationships between them

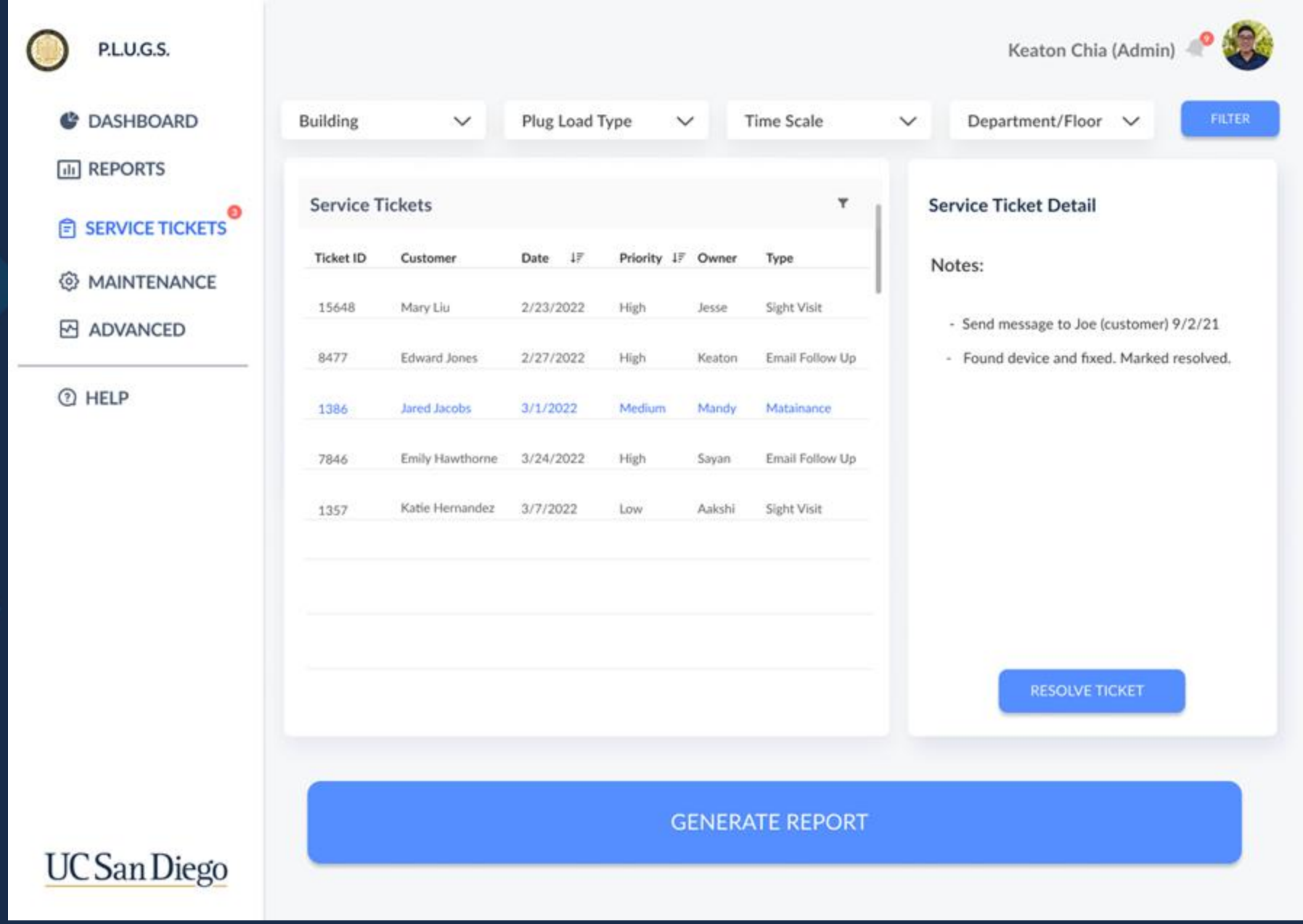


# BRICK & WEB UI


Web UI
BRICK API
UDP
BACnet/IP
BACnet/IP
PLUG LOAD CONTROLLER
UCSD DEVICE NETWORK
BERT BACNET GATEWAY
JCI VIRTUAL NAE
BRICK SERVER

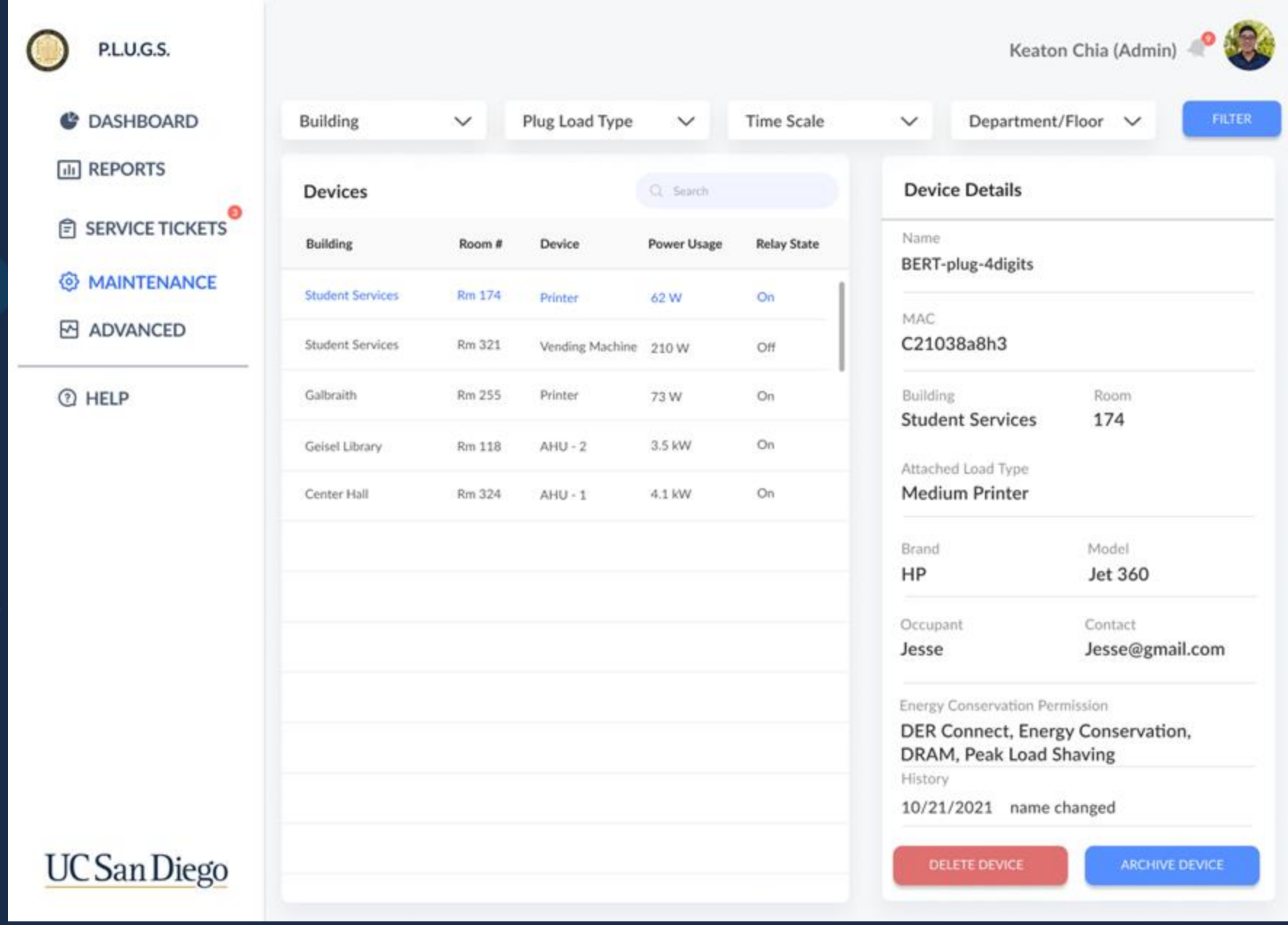
# Web UI
## Service Tickets

- Manage occupant requests
- Organize by action required
- Generate service order
  - Non-comm
  - Un-used
  - Changed Load



# Web UI Maintenance

- Control PLC
- Update meta-data
- Deploy or remove PLCs



# ADVANCED PLC STRATEGIES

Prime Directive: building services must serve occupants and keep them happy!

LESS RISK

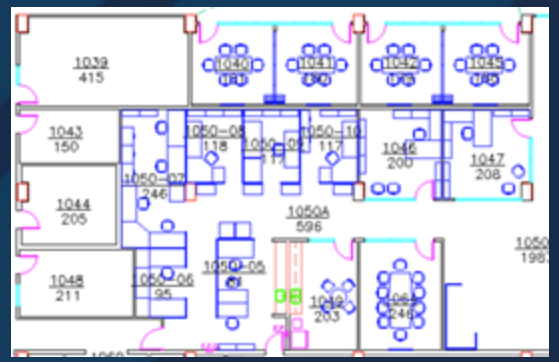


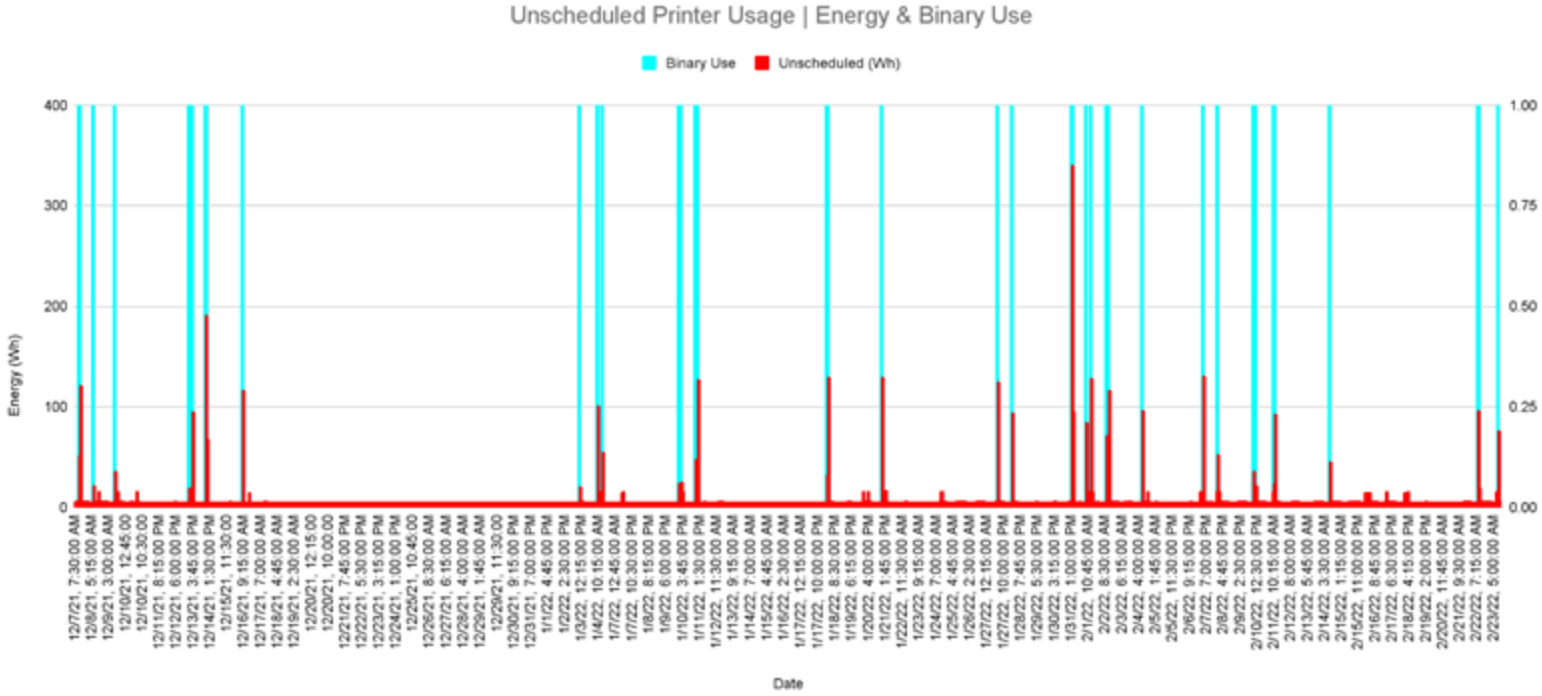
MORE RISK

- Static Schedules *(off from 9pm to 6am and weekends)*
- Location Based *(on when occupant on campus)*
- Occupancy Sensors *(on when in room)*
- Usage Schedule *(on when we predict user will need power)*
- Inferred Occupancy *(predict occupancy of other rooms)*
- Behavior Changes *(demand response similar to OhmConnect)*

# CASE STUDY

- Medium Printer
- Single user
- ~ 3 months activity
- Located in cubicle within open space
- Geisel Library - admin/library processing area

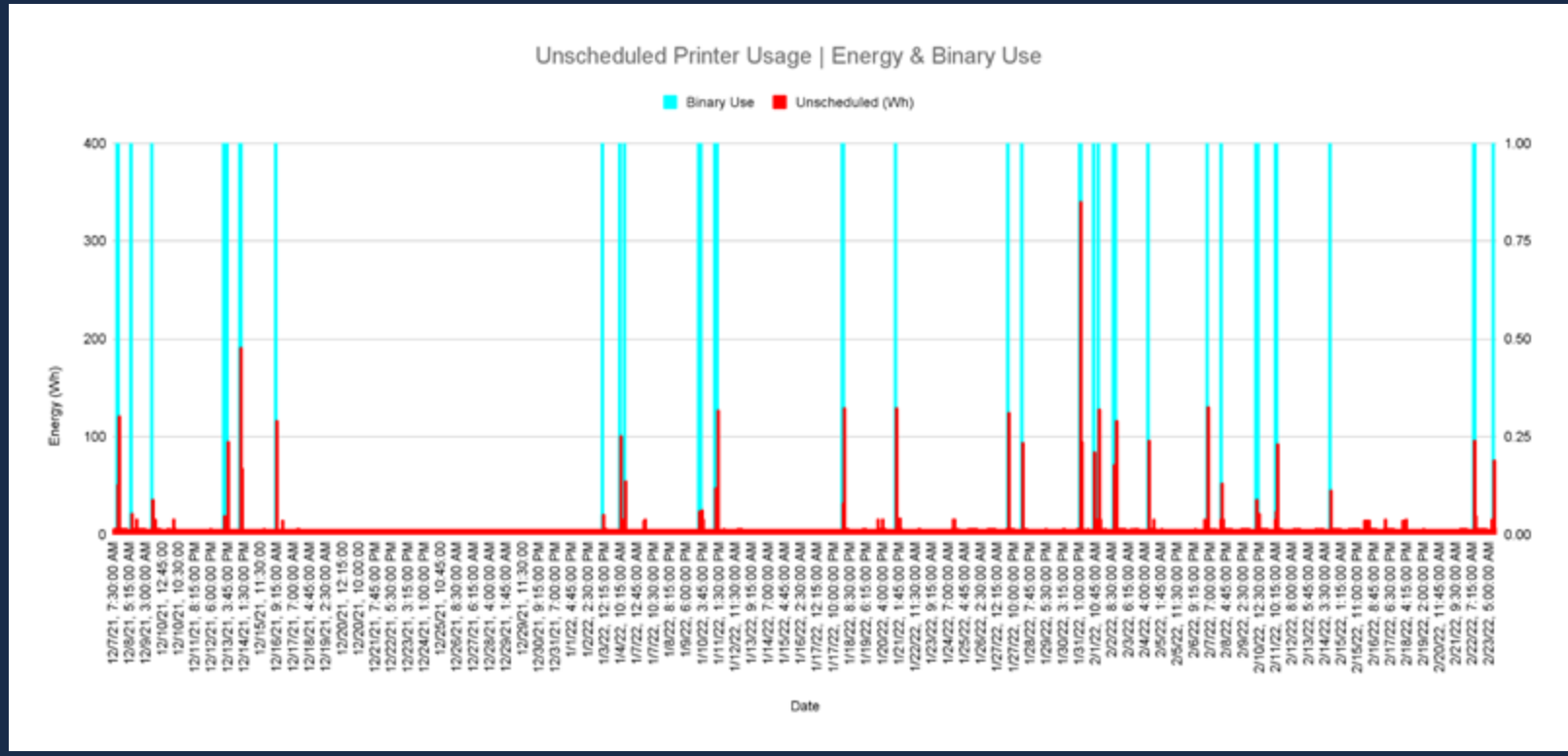


# CASE STUDY

## LAYERED APPROACH

- 3 months
- 41 kWh: Uncontrolled
- 21 kWh (47% savings): Static Scheduling (off 9pm-6am and weekends)
- 12 kWh (69% savings): Upper/lower tightening
- 10 kWh (74%): Usage Scheduling
- (85%+?) ML, inferred Occupancy/location



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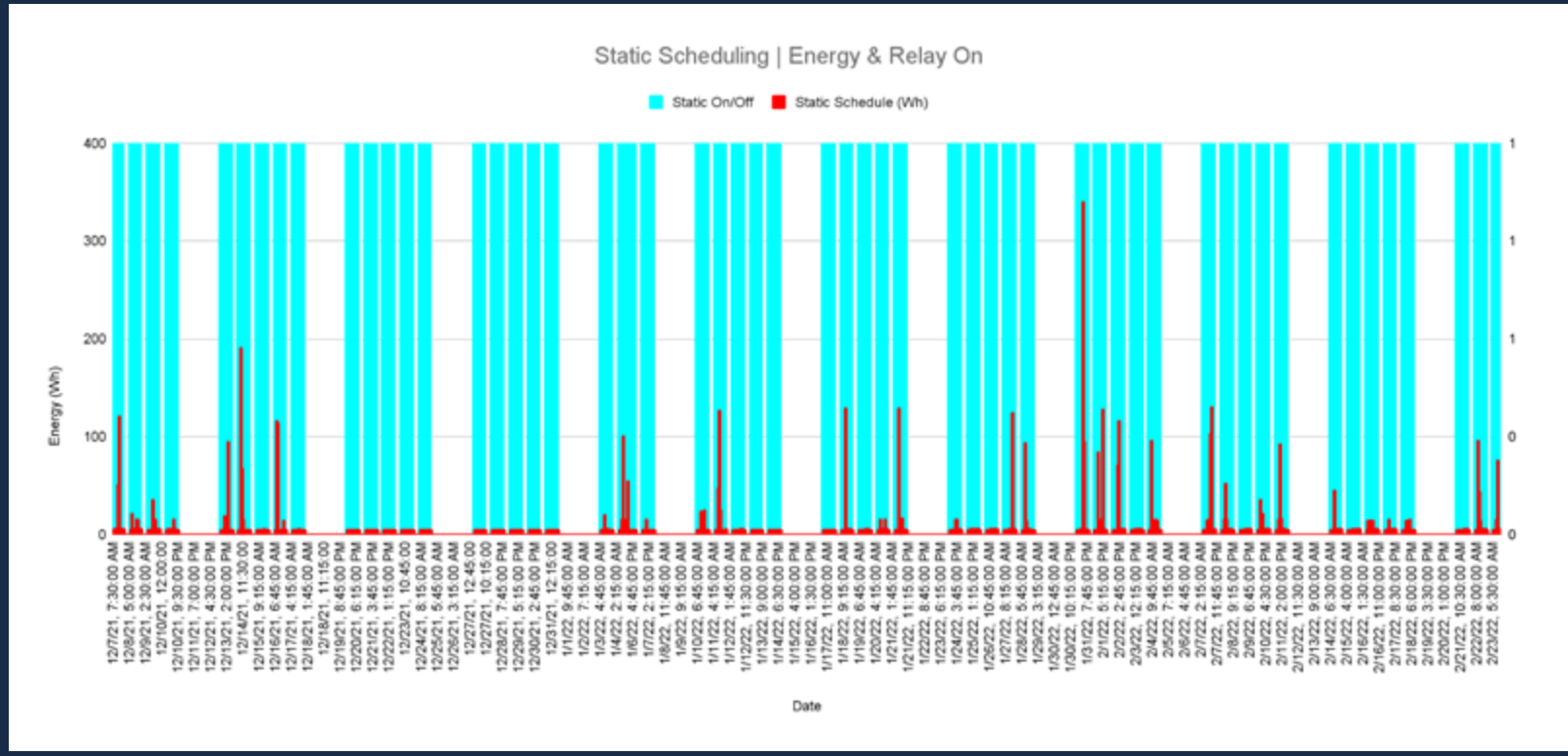

# CASE STUDY

## AGGREGATION MAP OF USAGE

- Aggregate usage per time and day
- Use to tighten upper and lower scheduling limits
- Identify usage gaps during occupied hours
- Rolling data set with more recent weeks weighted higher

**Usage Heatmap (no scheduling)**

| TIME | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
|---|---|---|---|---|---|---|---|
| 8:00:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8:15:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8:30:00 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 8:45:00 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| 9:00:00 | 0 | 1 | 0 | 1 | 2 | 0 | 0 |
| 9:15:00 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| 9:30:00 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| 9:45:00 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 10:00:00 | 0 | 4 | 0 | 0 | 1 | 0 | 0 |
| 10:15:00 | 0 | 3 | 0 | 0 | 1 | 0 | 0 |
| 10:30:00 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 10:45:00 | 1 | 5 | 0 | 0 | 0 | 0 | 0 |
| 11:00:00 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11:15:00 | 1 | 0 | 2 | 0 | 0 | 0 | 0 |
| 11:30:00 | 0 | 4 | 6 | 3 | 3 | 0 | 0 |
| 11:45:00 | 1 | 1 | 0 | 0 | 3 | 0 | 0 |
| 12:00:00 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 12:15:00 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| 12:30:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12:45:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13:00:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13:15:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13:30:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13:45:00 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| 14:00:00 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14:15:00 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 14:30:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14:45:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15:00:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15:15:00 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15:30:00 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15:45:00 | 3 | 1 | 0 | 1 | 0 | 0 | 0 |
| 16:00:00 | 0 | 2 | 0 | 1 | 0 | 0 | 0 |
| 16:15:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

# CASE STUDY

## LAYERED APPROACH

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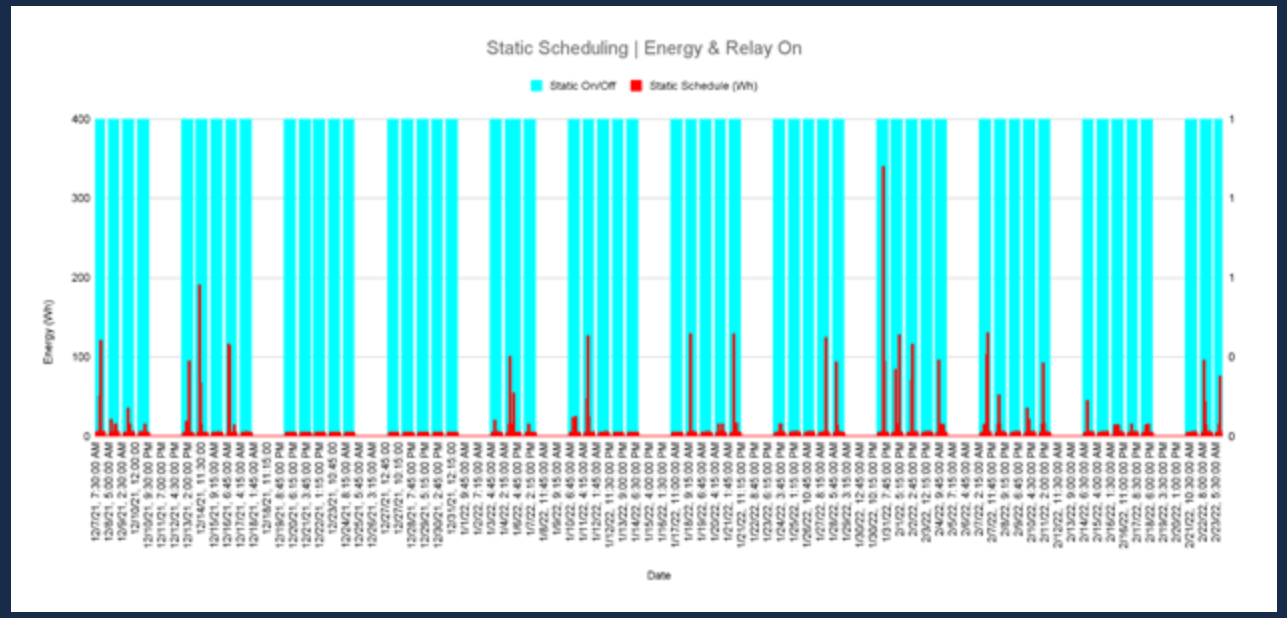


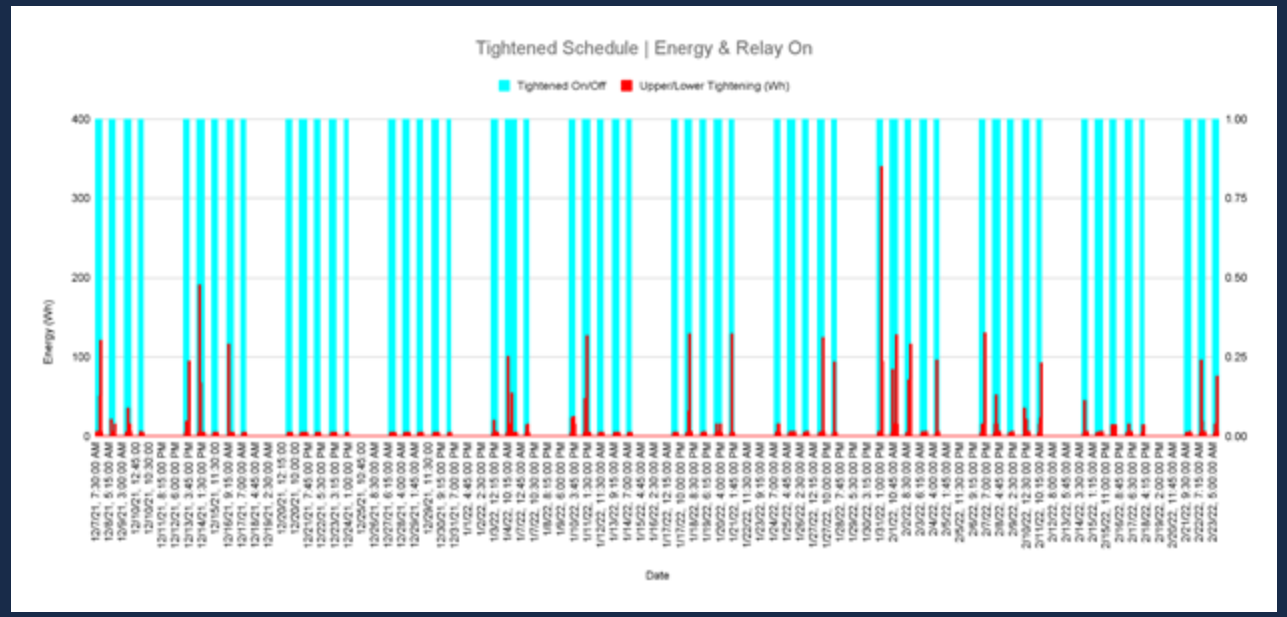

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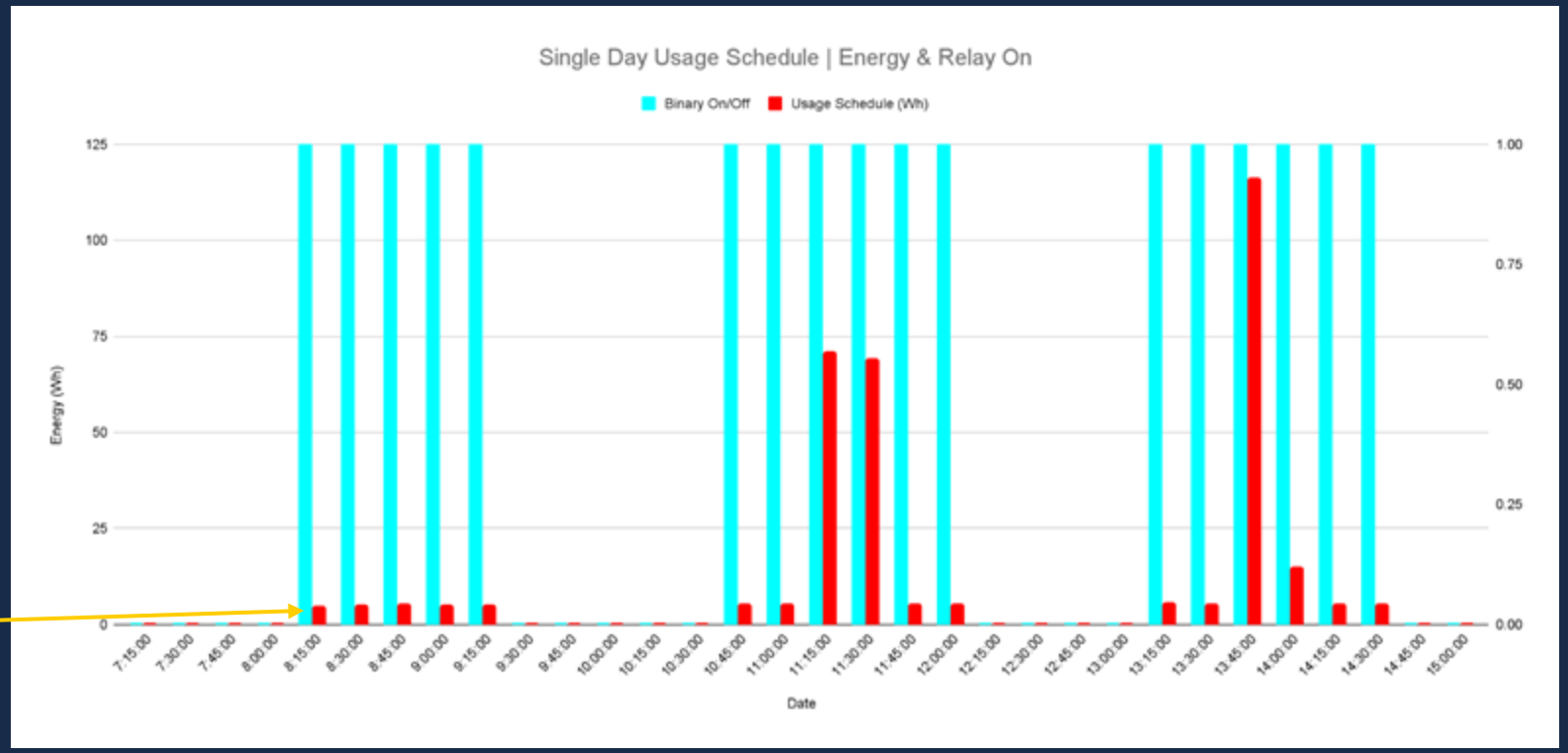



Single day showing 'off' gaps during occupied hours

# IMPLEMENTATION BARRIERS

- Priority to keep occupants satisfied
- Choose safest option, set it and forget it
- What is needed?
  - Information for decision (ie. context, use, location)
  - Decision to the decision maker
  - Scalability

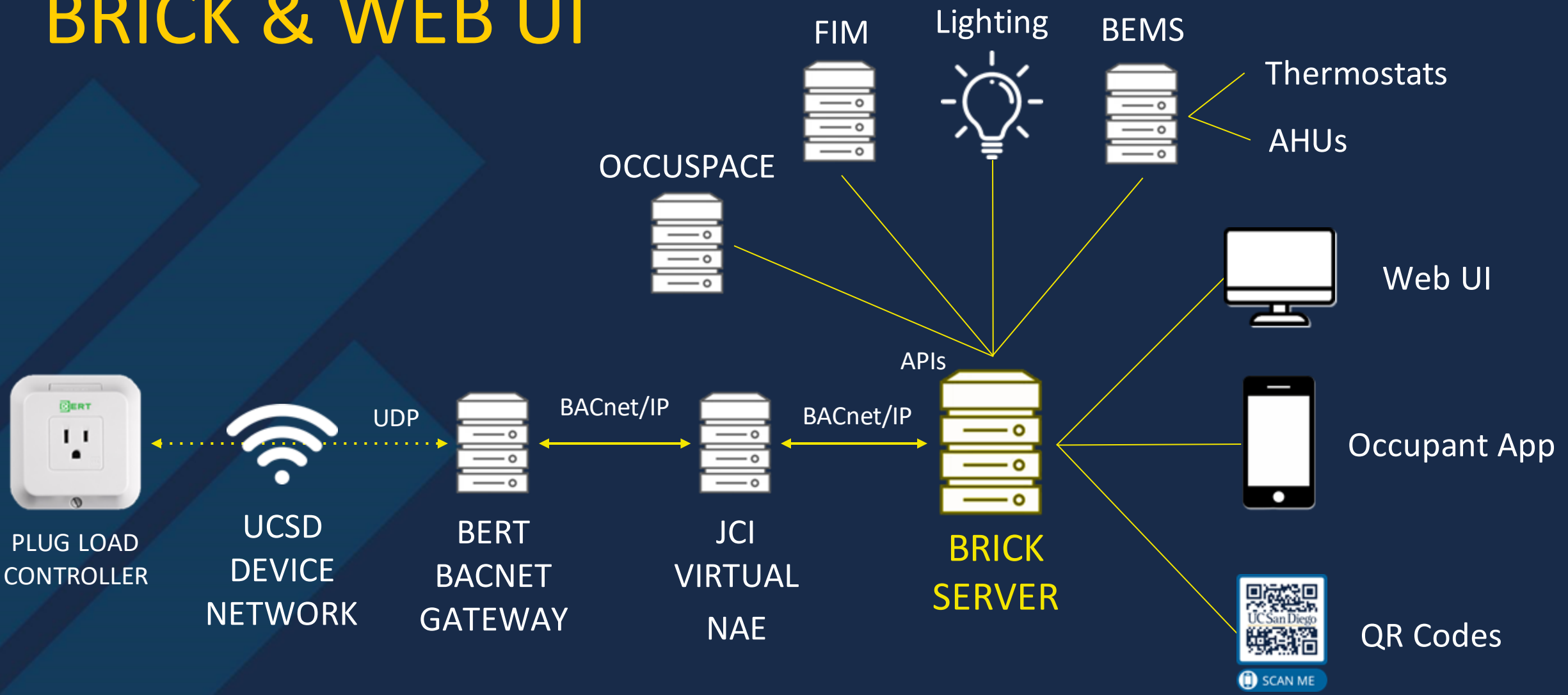
# APPLICATION OF STRATEGIES

Different strategy based on device and room type. For example:

| Strategy -> | Static | Location | Occ Sensor | Usage Schedule |
|---|---|---|---|---|
| TV in Lobby | best | no | maybe | no |
| TV in Single Office | yes | maybe | maybe | best |
| TV in Shared Space | yes | no | maybe | best |
| TV in Conference Room | yes | no | best? | maybe |

Ability to group PLCs by load and room type allows for batch scheduling

# BRICK & WEB UI


FIM
Lighting
BEMS
Thermostats
AHUs
OCCUSPACE
Web UI
APIs
UDP
BACnet/IP
BACnet/IP
Occupant App
PLUG LOAD CONTROLLER
UCSD DEVICE NETWORK
BERT BACNET GATEWAY
JCI VIRTUAL NAE
BRICK SERVER
QR Codes
SCAN ME

# SUMMARY

- Communicate with occupants (emails, fliers, impact)
- Minimize steps to resolve issues (dedicated email address)
- Be prepared for CHANGE! Have process for managing updates (location, load, approvals)
- Be able to make quick optimization decisions by having access to the right information and having decision makers onboard

# Question & Answer

MAY
17-19
2022

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# Thank You!

Kim Trenbath
Kim.Trenbath@NREL.gov