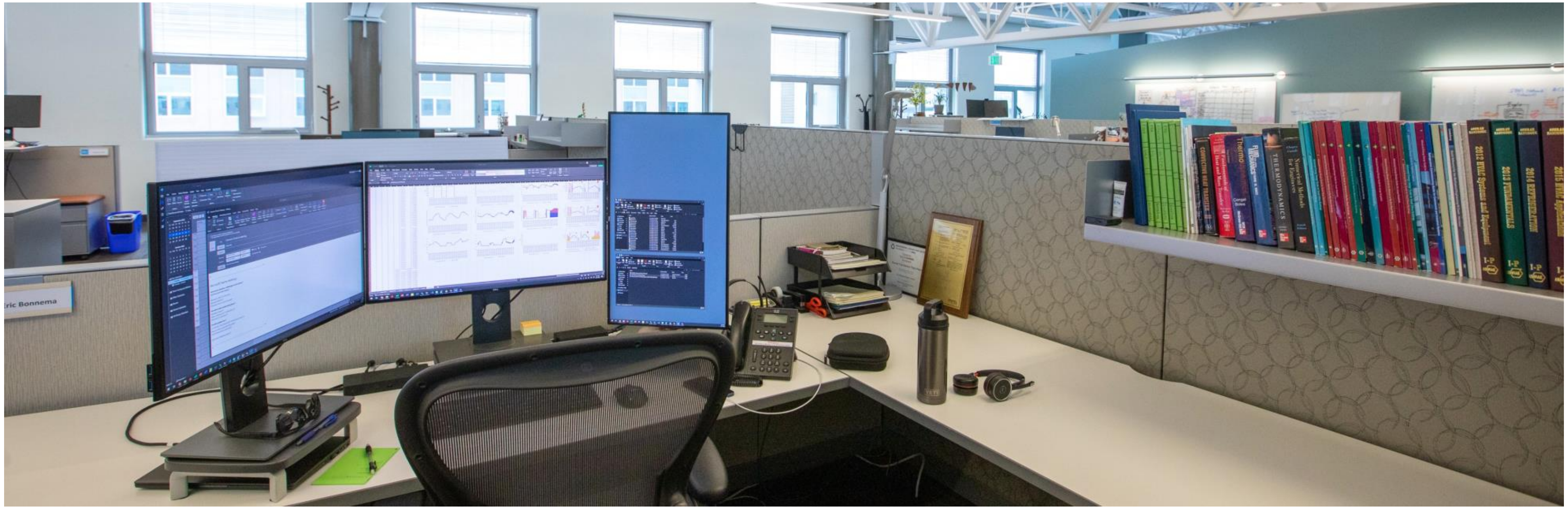
Impact of the Better Building Alliance Plug and Process Loads Technology Research Team



National Renewable Energy Laboratory (NREL)
Dr. Kim Trenbath, Innovation Lead for Systems Technology R&D
720-434-9508 Kim.Trenbath@NREL.gov
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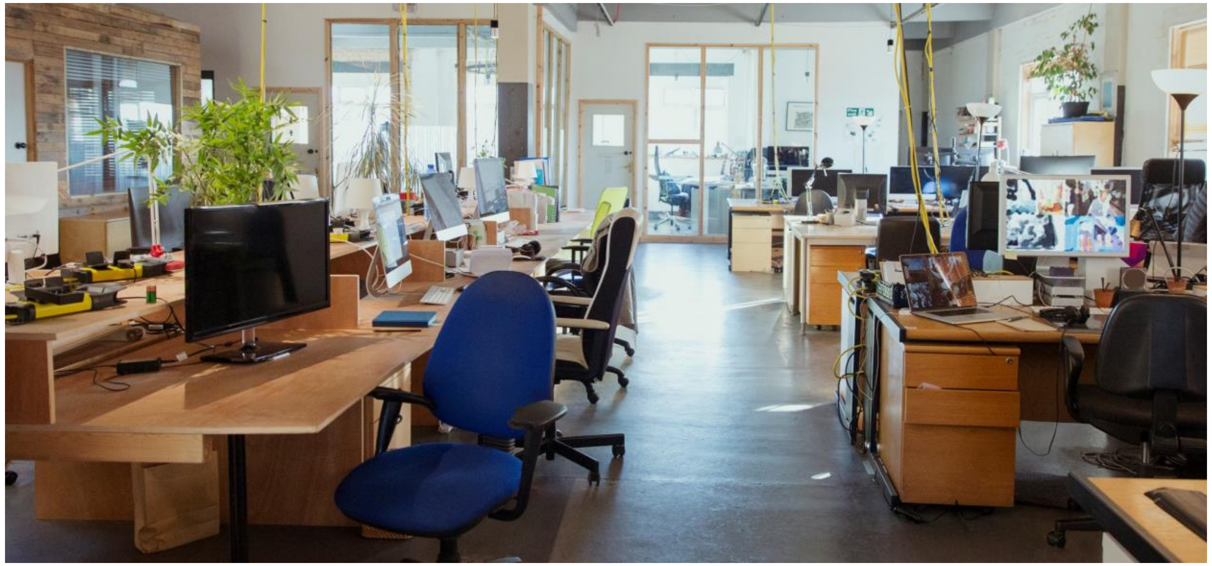
Project Summary

Objective and Outcome

The Better Buildings Alliance (BBA) Plug and Process Loads (PPLs) Technology Research Team (TRT) characterizes commercial building PPLs and technology pathways, identifies opportunities for reducing carbon emissions through PPL advanced technologies and management strategies, and deploys market findings and strategies to commercial building owners and stakeholders.



Team and Partners

National Renewable Energy Laboratory (NREL):

- **Dr. Kim Trenbath**, Technical Lead and Senior Research Engineer
- **Amy LeBar**, Research Engineer, Mechanical Engineering
- **Omkar Ghatpande**, Research Engineer, Electrical Engineering
- **Robin Tuttle**, Stakeholder Engagement Manager.

Select Collaborators: Pacific Northwest National Laboratory (PNNL), Lawrence Berkeley National Laboratory (LBNL), California Plug Load Research Center at the University of California Irvine, University of California San Diego, U.S. Environmental Protection Agency ENERGY STAR®

Stats

Performance Period: ongoing

DOE Budget: $394,000 for FY23, Cost Share: $0

Milestone 1: 6-8 Page Process Loads Resource for BBA Partners (published 1/12/23)

Milestone 2: Two Technology Research Team webinars (one completed 2/09/23; second planned for 8/1/23)

Milestone 3:Healthcare Sector Industry Engagement and Market Transformation (ongoing)

Plug and process loads (PPLs) are plug-in and hardwired loads not associated with other major building end uses.

- PPLs include a wide range of devices and appliances with varying levels of energy consumption.
- There can be thousands of individual PPLs in a commercial building – the energy adds up!

Motivation & Problem Statement

PPLs are challenging to manage and reduce because they are diverse, numerous, and highly occupant-dependent.

PPLs account for up to 47% of commercial building energy use, and much of that load is unknown.

In the past, when control technologies were implemented: Occupant frustration due to technology unknowns led to unfavorable savings numbers, further discouraging adoption.

Problem Statement: PPLs are a large part of whole-building energy use and a multifaceted challenge to assess, reduce, and control.

PPL Team Impact and Alignment

Impact: Plug and Process Loads (PPL) Technology Research Team

Kim Trenbath
Technology Team Lead

Amy LeBar
Research Engineer

Omkar Ghatpande
Research Engineer

Robin Tuttle
Project Manager

PPL@nrel.gov

Impact

The BBA PPL Team is

1. Characterizing commercial building PPLs and technology pathways
2. Identifying opportunities for reducing carbon emissions through PPL advanced technologies and management strategies
3. Deploying results and market strategies to commercial building owners and stakeholders

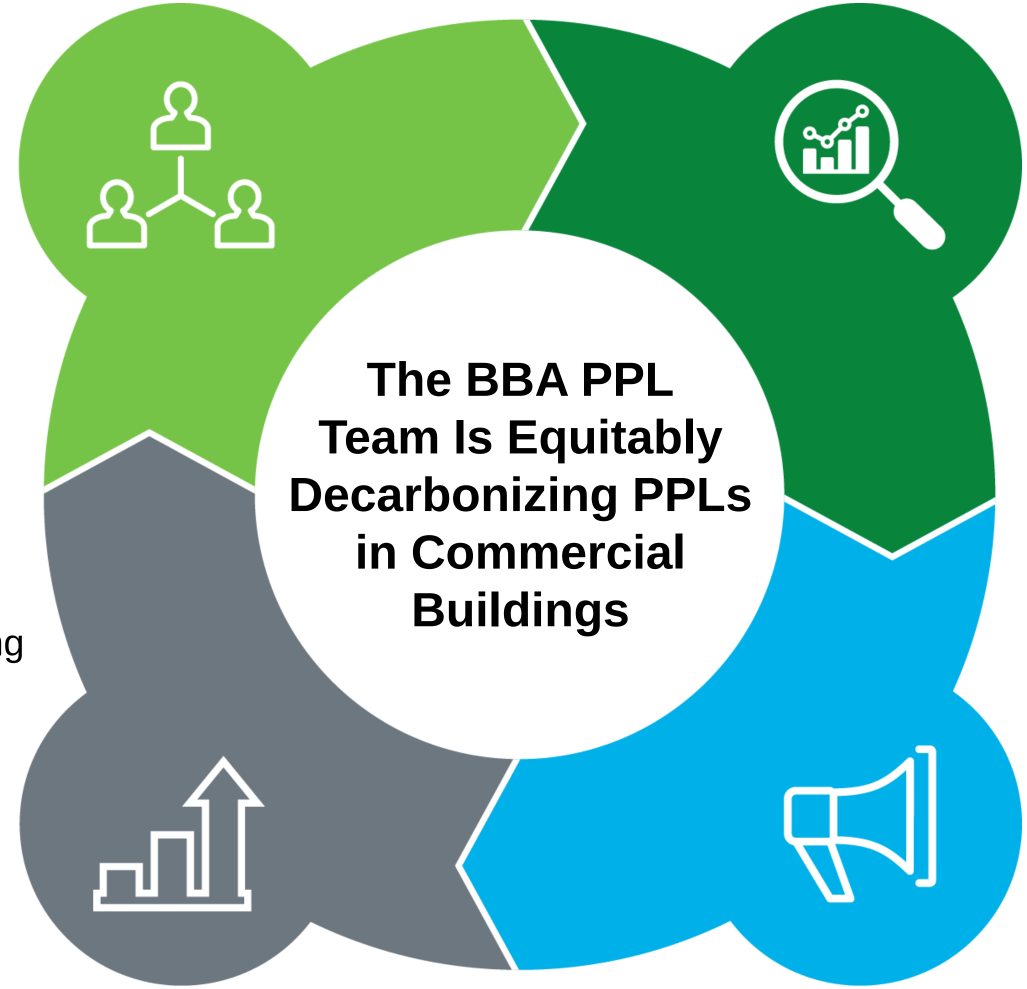
Opportunity: PPL ENERGY SAVINGS OF UP TO 30%

Impact & Alignment

Impact	Increase building energy efficiency	Accelerate building electrification	Transform the grid edge at buildings
Building owners and other stakeholders know PPL as a % of whole building energy use and can further disaggregate PPLs	✓		✓
Building owners implement strategies (including low-cost or no-cost) to control and reduce PPLs	✓		
Increase in % installed energy efficient devices and equipment	✓		
Plug load savings of up to 30% in commercial buildings	✓		
Year-over-year analysis and dissemination of technologies and strategies to control PPLs	✓		✓
Increased uptake of commercialized technologies	✓		✓
In the future, affordable technologies available for building owner purchase	✓		
Increased PPL electrification in commercial buildings due to published resources and research papers		✓	
Developed PPL control technologies that transform the grid edge at buildings		✓	✓

PPL Team Approach

Approach



1. Determine Stakeholder Needs

- Engage with building owners, manufacturers, researchers, DOE, and other experts
- Document opportunities & challenges

2. Conduct Research

- Characterize market
- Set up data aggregation
- Data collection for product validation
- Support technology development
- Analyze data and develop conclusions
- Identify best practices

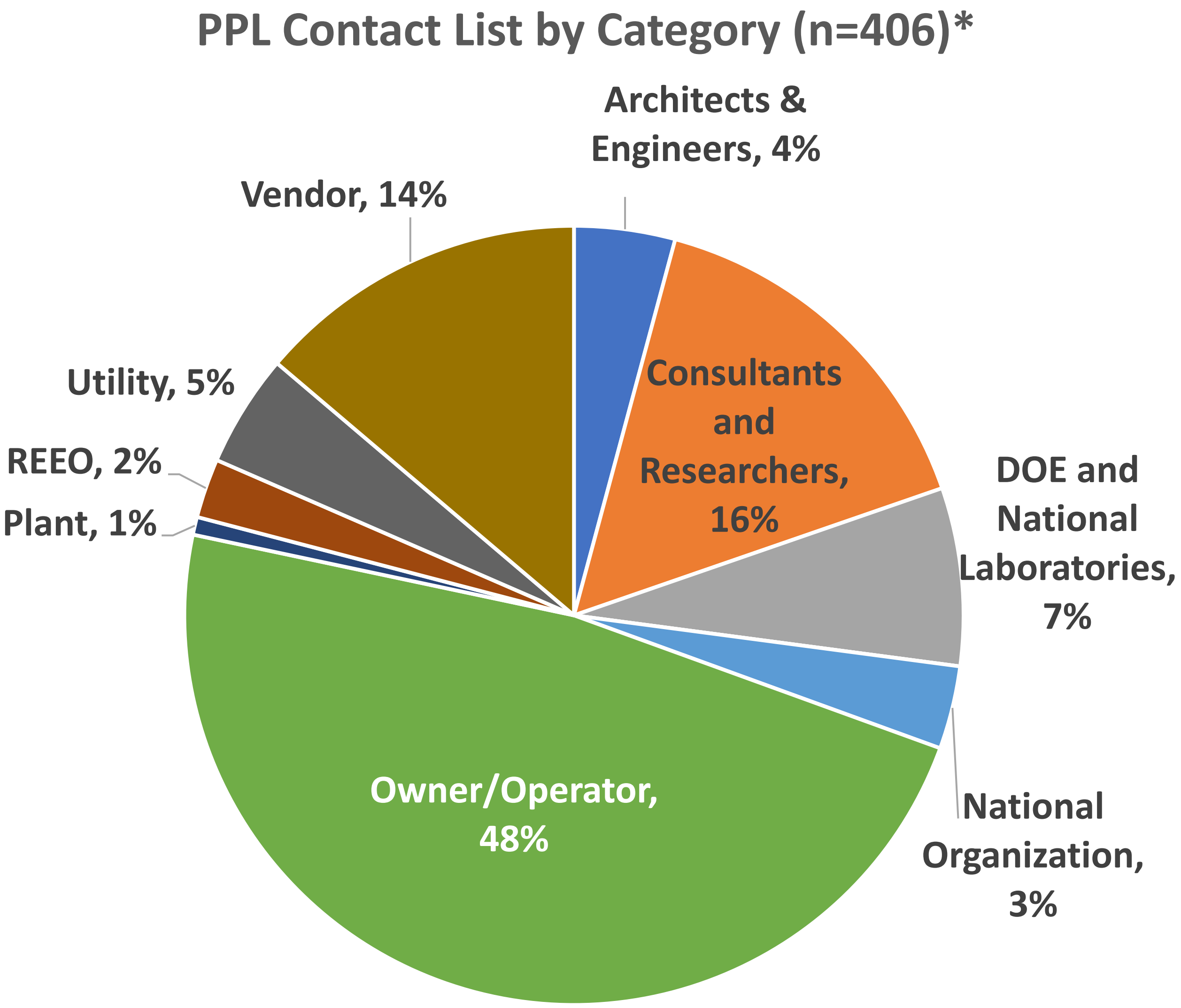
3. Publicize Results

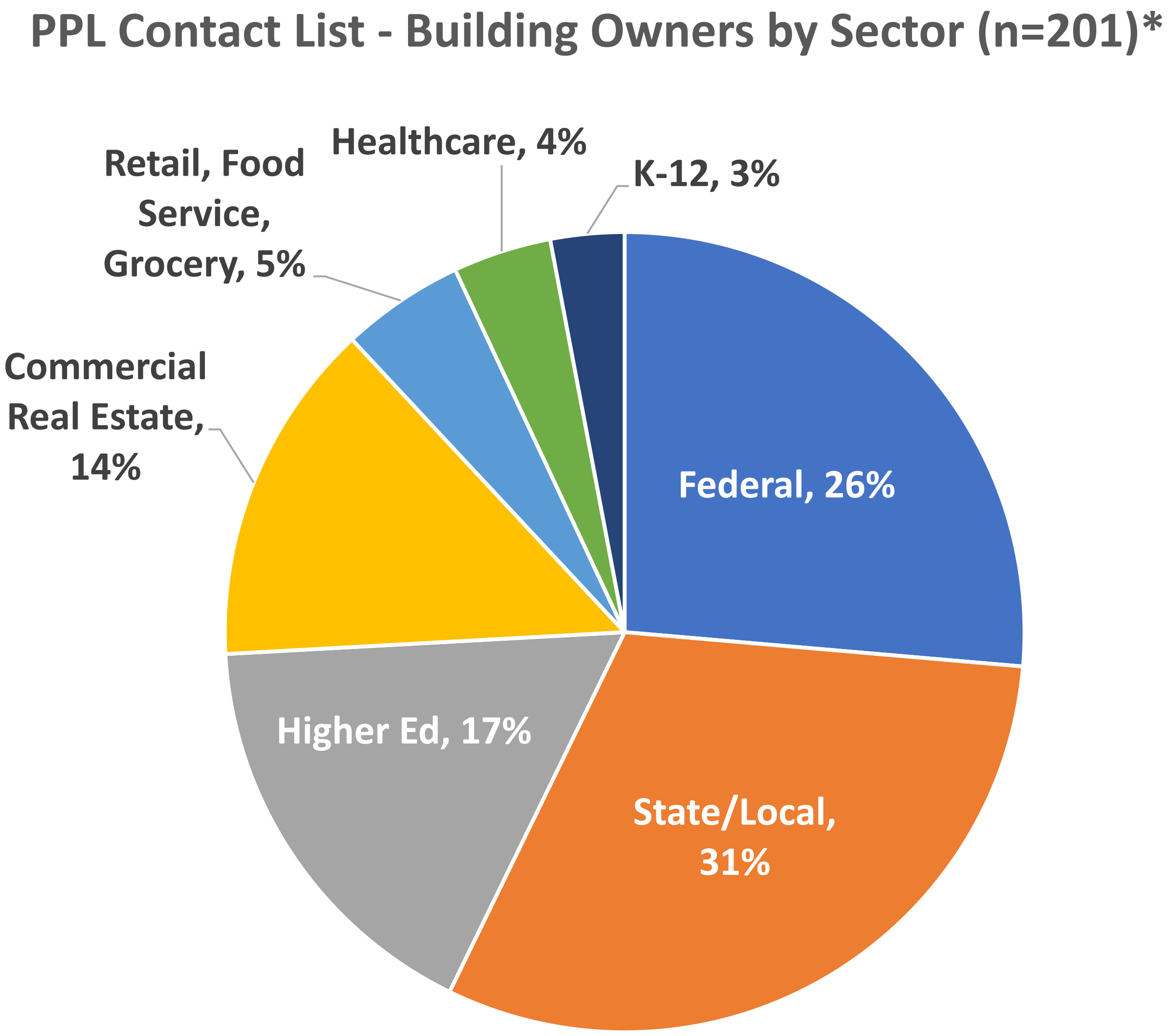
- Address stakeholder needs
- Publish fact sheets, guides, and other resources
- Publish research papers
- Publications posted on our website

4. Deploy Strategies

- Disseminate resources to building owners & policy makers
- Communicate research to other experts and manufacturers
- Give presentations in webinars and conferences
- Provide building owners with technical assistance

Partnerships and Amplification Channels





*Data as of Nov 2022

Approach: Barriers and How To Overcome

Barrier	Mitigation
PPL energy use highly dependent on occupants	NREL communicates no-cost, low-cost strategies on webinar, encouraging building operator uptake
PPL control technologies struggle in the market	NREL research provides market insights to technology developers and manufacturers
	NREL works on occupant-independent strategies such as energy efficiency specifications in procurement and product development
Current technology solutions have low ROI	NREL informs how to pair management strategies with control technology to increase ROI

PPL Team Progress

Progress: FY21 - FY23 Accomplishment Summary

8 PPL-led webinars

5+ guest presentations

10 quarterly updates

10 resources for BBA partners

1 conference paper

2 utility incentive updates

10 strategic working group meetings

1 patent

Progress: Determine Stakeholder Needs

Stakeholder Engagement Summary

- Quarterly Strategic Working Group calls
- Regular engagement with BBA Sector Leads
- One-on-one calls
  - Technology manufacturers
  - Partners
- Integrated Lighting Campaign
- PNNL ARC Survey
- MELs Round Table: 6/14/23 - 6/16/23
- Medical Imaging Equipment (ASHE): 7/19/23
- Quarterly NEMA ARC Task Force Meetings
- Nexus Labs Workshop: 12/7/23
- Pathways to PPL Efficiency and Control study

Strategic Working Group

Purpose: to share research updates and provide a community for collaboration for PPL researchers. Meets every quarter.

Organization	Contact
ACEEE	Rohini Srivastava
CalPlug	Katie Gladych
CEC	Felix Villanueva
DOE	Wyatt Merrill
GSA	Kinga Porst-Hydras
LBL	Alan Meier
PNNL	Michael Myer

Date	Discussion Topic(s)
03/16/21	Welcome Wyatt Merrill, 2 CEC projects kicking off: UCSD BERT plug load project (NREL supporting) and Plug Load Energy Testing to inform Codes and Standards (PLETICS)
06/23/21	Controlled receptacles markings
09/15/21	Healthcare imaging equipment, LBL paper on home healthcare devices, controlled receptacle markings survey
12/15/21	Medical imaging equipment, low carbon pilot, CalPlug and Industrial Assessment Centers
03/10/22	Emerging technologies for PPLs and MELs, decarbonization strategies for PPLs and MELs, understanding and addressing needs of disadvantaged communities
06/22/22	CalPlug Workshop debrief, DOE MELs roundtable
09/20/22	Round robin of project updates, upcoming EPIC Symposium and CalPlug Workshop
12/15/22	What does the future of PPL controls look like?
03/02/23	Bob Dahowski presents on "Characterizing Plug Load Energy Use and Savings Potential in Army Buildings"

Market Stakeholder Workshop

OBJECTIVES: Engage with members of the smart buildings industry to (1) inform the Pathways to PPL Efficiency and Control effort, and (2) share current and future PPL efficiency and control strategies and technologies.

IMPACT

- 23 Nexus Labs members can act on market knowledge of PPL efficiency and control, increasing energy efficiency and update of PPL control strategies.
- Building owner and industry-provided insight for PPL efficiency and control study.

KEY STAKEHOLDERS

Dartmouth College; Cushman & Wakefield; The Durst Organization; Building Intelligence Quotient Group; Smart Building Services LLC; Deepthink Buildings; Interval Data Systems; Liberty Mutual Insurance; Montgomery Technologies; JBG SMITH; University of New Hampshire; Dialog; TRC Companies, Inc.; Telecommunications Industry Association; Siemens; Cbi; Dream Unlimited; Schneider Electric; PulseIQ; Intellimation LLC

Progress: Conduct Research

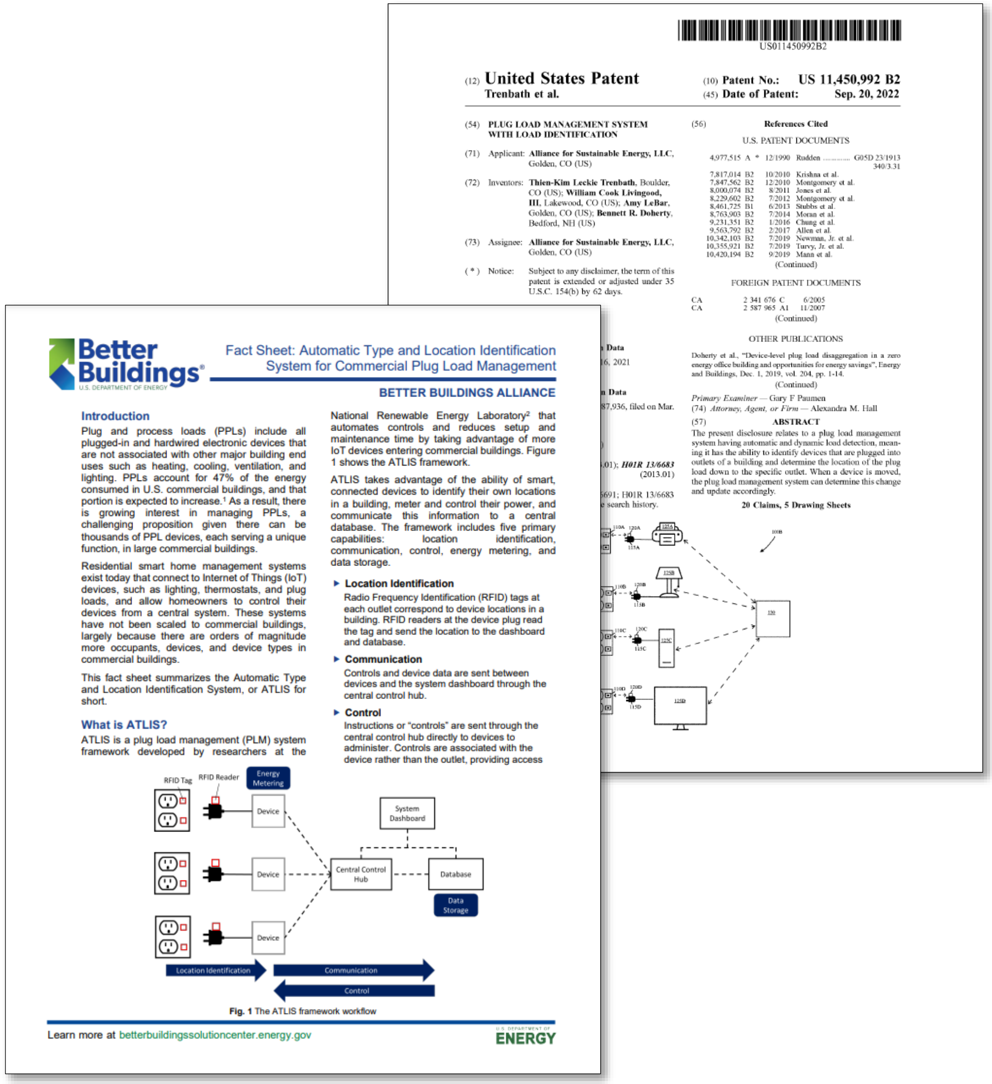
ATLIS: Automatic Type and Location Identification System

RESEARCH QUESTION: How can a PLM system automatically identify the location, energy use, and operating state of every device in a commercial building so that (1) controls can be automatically applied, and (2) labor hours required for setup and maintenance can be minimized?

IMPACT

- Novel plug-and-play PLM system that automatically tracks devices as they move throughout a building, accurately applies controls, monitors device energy.
- Achieves PPL energy savings of up to 30%.
- Supports demand flexibility.

Conference Paper, 2021: link
Fact Sheet, 2021: link
Patent, 2022: link



(12) United States Patent
Trenbath et al.
(10) Patent No.: US 11,450,992 B2
(45) Date of Patent: Sep. 20, 2022

(54) PLUG LOAD MANAGEMENT SYSTEM WITH LOAD IDENTIFICATION

Better Buildings® U.S. DEPARTMENT OF ENERGY

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

ENERGY

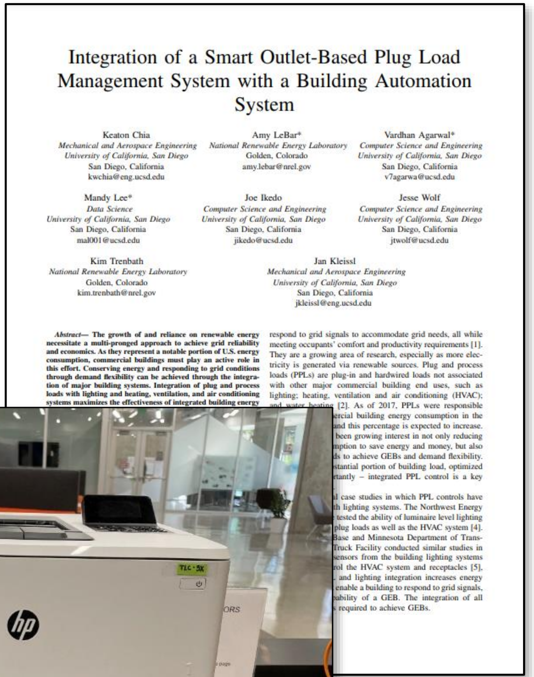
PPL Control / BAS Integration with UC San Diego

RESEARCH QUESTION:
How can we integrate a PLM system with a commercial building automation system (BAS)?

IMPACT

- The first plug load-BAS integration project.
- Whole-building integration is necessary for grid-interactive efficient buildings, and PPLs have historically been widely excluded from BAS integration projects.
- NREL provides PPL expertise in an advisory role.
- Community-based solution allows commercial building occupants to switch on hard-to-reach outlets through web interface.

TRT Webinar, 2022: link
IEEE Grid Edge Conference Presentation, April 10-13: link



Integration of a Smart Outlet-Based Plug Load Management System with a Building Automation System

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Amy LeBar*, National Renewable Energy Laboratory, Golden, Colorado, amy.lebar@nrel.gov
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Kim Trenbath, National Renewable Energy Laboratory, Golden, Colorado, kim.trenbath@nrel.gov
Jan Kleissl, Mechanical and Aerospace Engineering, University of California, San Diego, San Diego, California, jkleissl@eng.ucsd.edu

Abstract— **The growth of and reliance on renewable energy necessitate a multi-pronged approach to achieve grid reliability and economics. As they represent a notable portion of U.S. energy consumption, commercial buildings must play an active role in this effort. Conserving energy and responding to grid conditions through demand flexibility can be achieved through the integration of major building systems. Integration of plug and process loads with lighting and heating, ventilation, and air conditioning systems maximizes the effectiveness of integrated building energy**

respond to grid signals to accommodate grid needs, all while meeting occupants' comfort and productivity requirements [1]. They are a growing area of research, especially as more electricity is generated via renewable sources. Plug and process loads (PPLs) are plug-in and hardwired loads not associated with other major commercial building end uses, such as lighting; heating, ventilation and air conditioning (HVAC);

KEY PARTNERS

UC San Diego, BERT Brain, Johnson Controls

Progress: Publicize Results

Assessing and Reducing Guides

OBJECTIVE:
Encourage adoption of PPL control and reduction strategies through educating end users (building owners, facility managers, etc.)

IMPACT

- Achieve PPL reductions in buildings by institutionalizing measures, benchmarking, appliance-specific strategies, and having a champion.
- Outline control technologies including integrated controls, smart outlets, automatic receptacle controls, and advanced power strips.
- Our most shared resource.

Retail Guide, 2020: link
Office Guide, 2020: link

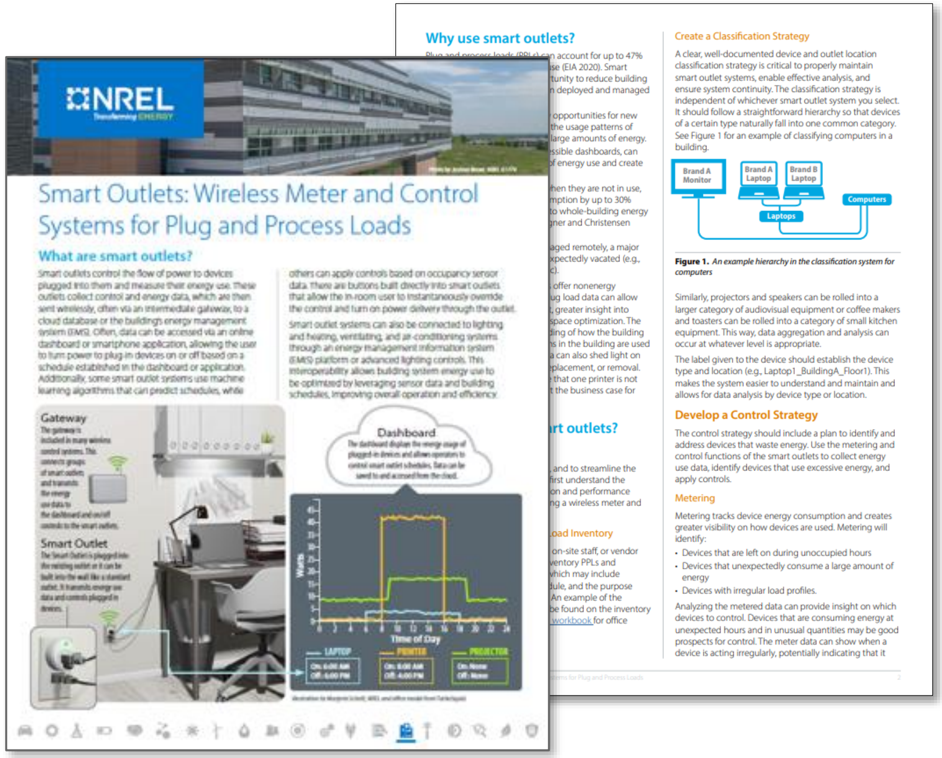
Smart Outlets Guide

OBJECTIVE:

Encourage adoption of smart outlets through educating end users (building owners, facility managers, etc.)

IMPACT

- Quick-read, manufacturer-neutral resource on smart outlets that provides guidance to building managers on how to develop a control strategy, procure the technology, and engage occupants.
- Smart outlets control the flow of power to devices plugged into them and measure their energy use, leading to energy savings, remote access to data, identification of large plug loads.



Guide, 2020: [link]()

KEY STAKEHOLDERS

Smart outlet manufacturers: Best Energy Reduction Technologies (BERT), Sapient Industries, WattIQ, Keewi

Automatic Receptacle Controls

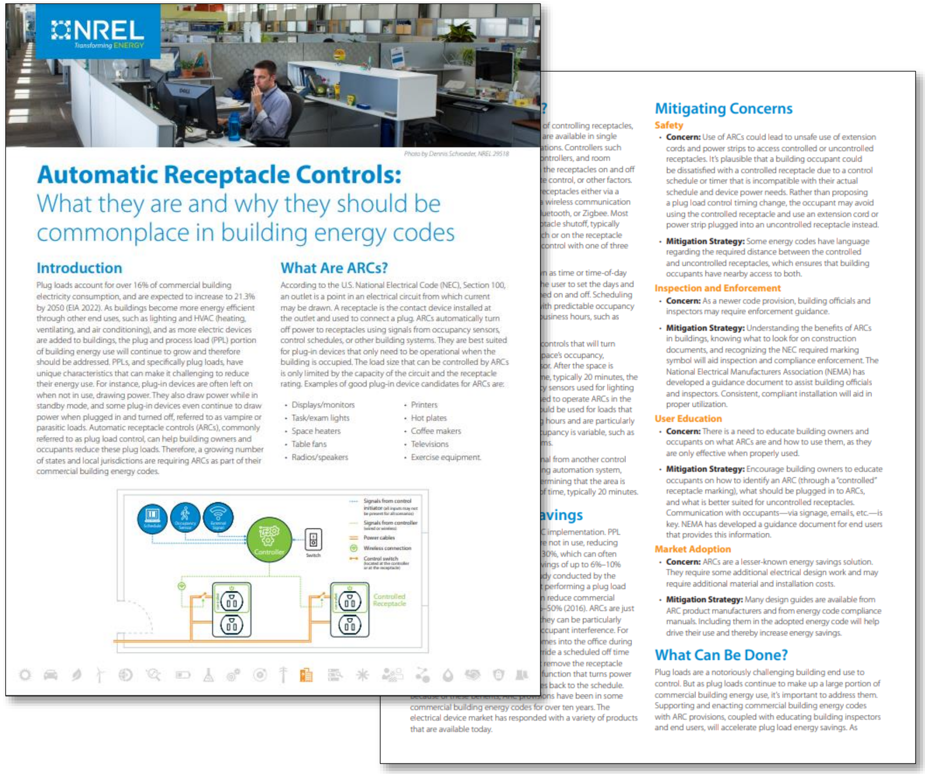
OBJECTIVE:

Provide fact sheet for energy code adopters to promote uptake of automatic receptacle controls (ARCs).

IMPACT

- Increases uptake of ARCs by providing a fact sheet for ARC users and building code adopters.
- Outlines how ARCs work and how to mitigate some of the more challenging aspects of the technology to promote adoption.
- Through this fact sheet NREL addressed a market need identified by NEMA ARC Task Force.

Fact Sheet, 2022: link



KEY STAKEHOLDERS

NEMA, Acuity, Audacy, Cooper Lighting, Eaton, Hubbell, IDEAL, Legrand, Leviton, Lutron, Schneider Electric

Reducing Process Loads and Refrigeration Unit Energy Consumption

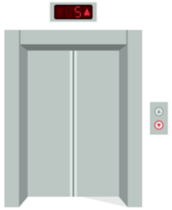
OBJECTIVE: Introductory guide for commercial building process loads and is intended to help commercial building owners and operators reduce process load energy consumption.

IMPACT

- Building owners have resource and guidance to assess and reduce larger PPLs, or process loads.
- Achieves energy efficiency through equipment procurement and power settings.
- A step towards electrification (load reduction).





Resource, 2022: link


NREL Transforming ENERGY

Reducing Commercial Building Process Loads and Refrigeration Unit Energy Consumption

Introduction

Plug and process loads (PPLs) are plug-in and hardwired loads in a building that are not associated with heating, ventilating, and air conditioning; lighting; water heating; or other major equipment needed for basic building operation (Trenbath et al. 2020). PPLs make up 47% of U.S. commercial building energy consumption (see Figure 1)[1]. As building end uses become more energy efficient and PPLs become more common in commercial buildings, this percentage is expected to increase. Refrigeration makes up 10% of commercial building energy use and represents a significant opportunity for energy savings. Refrigeration and certain PPLs, such as elevators, enterprise servers, and commercial kitchen equipment, are often collectively referred to as "process loads" in buildings.

This resource is an introductory guide for commercial building process loads. It is intended to introduce commercial building owners and operators to this often overlooked end-use, and to help them reduce process load energy consumption. The resource will be helpful for any commercial building that has equipment in one or more of these five common commercial building process load categories: **food handling, refrigeration, internal mobility, data center and information technology, and water handling.** It outlines how to assess process loads in a building, describes the procedure for identifying loads to target for energy reduction, and provides an overview of reduction technologies and strategies for each category. Loads are alternatively categorized as either "plug-in" or "hardwired" to specify appropriate metering and reduction strategies.

Figure 1. Plug and process loads (including refrigeration) account for 57% of commercial building energy consumption. *Graph by Kristi Maisha, NREL; Data source: EIA (2020)*

or download a list of incentives from the Better Buildings Alliance PPL website listed under Policies and Incentives.

Upgrading appliances or equipment in commercial buildings can be challenging even when more efficient technology is available on the market.

most advanced models on the market. Determine when replacing the appliance or equipment will result in a favorable return on investment, factoring in equipment, installation, and commissioning costs, as well as energy consumption and circular economy factors.[2]

...quipment consolidation is another strategy for achieving ...nergy savings. During the inventory process, consider ...hether the function of many process loads could be ...andled by fewer pieces of equipment or devices. For ...xample, multiple fryers used at only part capacity could be ...onsolidated to a fewer number that still meets the demand.

...aintenance and Behavior

...aintaining process load equipment can not only ensure ...ngevity, but also keeps equipment and devices operating ...fficiently. Following a proper maintenance schedule can ...educe process load energy consumption.

...ccupant interaction with process loads also plays a key ...le in consumption, and energy-efficient behaviors should ...e promoted in a building. Encourage occupants to turn

...es for Each Process Load Category

Common Energy Saving Strategies			
Built-In Low-Energy Operation	Upgrade to Energy Efficient Equipment	Maintenance and Behavior	Design Strategies
●	●	●	●
	●	●	
●	●	●	●
●	●	●	●
●	●	●	

Kitchen Decarbonization

OBJECTIVE: Educate commercial building stakeholders about commercial kitchen decarbonization opportunities.

IMPACT

- Increased PPL electrification in commercial buildings
- Provides case studies kitchen equipment retrofits aimed at decarbonization in food service and hospitality sectors.
- Communicates specific decarbonization strategies such as replacing high energy equipment (refrigeration, stovetops, fryers, ice machines) with ENERGY STAR models, downsizing steamers, replacing gas with induction cooktops, improving ventilation.

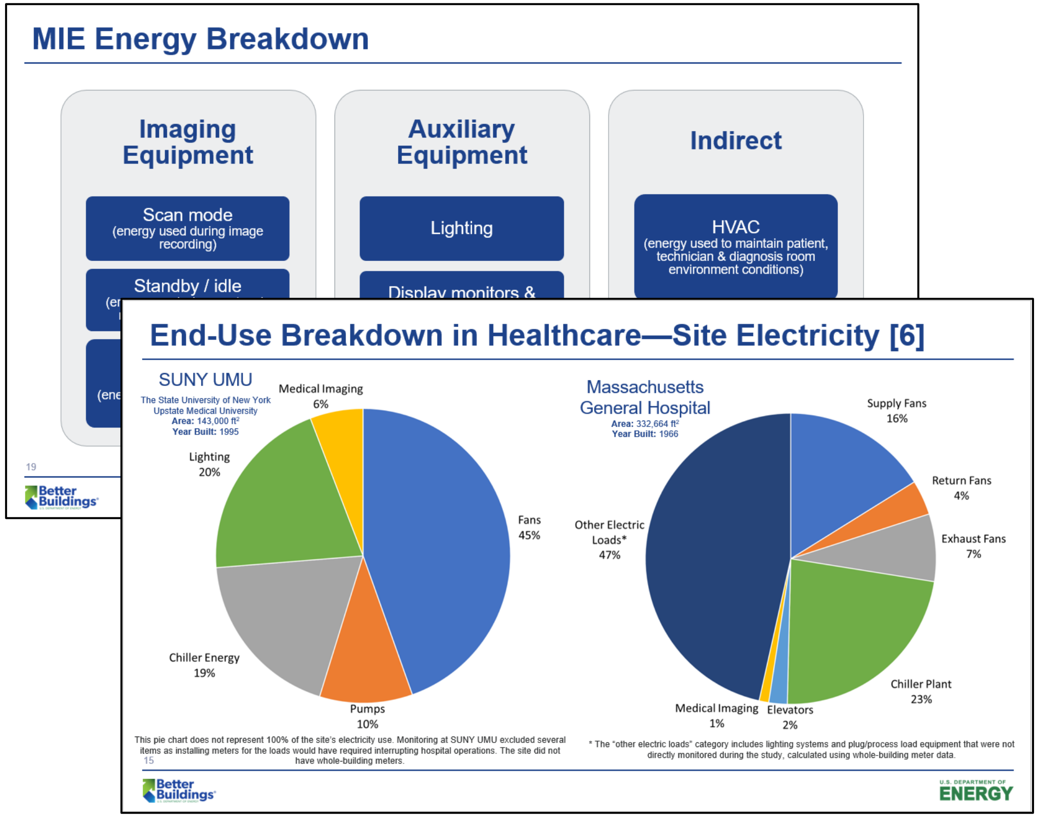
Guide, 2020: link
Conference paper, 2022: link

KEY STAKEHOLDERS

Better Buildings Alliance Partners, ICF, DOE

Medical Imaging Equipment Energy Efficiency

OBJECTIVE: Better Buildings Alliance (BBA) Healthcare Sector is interested in energy-efficient medical imaging equipment (MIE). Transform the MIE market by providing energy-efficient options.



IMPACT

- MIE energy use in healthcare buildings is around 5% of site energy use.
- There is a need for commercially available energy-efficient MIE options, but there are currently no U.S. MIE energy or efficiency standards.
- Identified MRI efficiency opportunities during the following modes: low power and ready-to-scan.
- NREL is providing technical validation and analysis in support of an MIE/MRI ENERGY STAR Specification.
- Informed U.S. government stakeholders during 2022 presentations.

KEY STAKEHOLDERS

US DOE, EPA ENERGY STAR, BBA Healthcare sector partners, Hospitals and Medical Centers (UC Davis Health, U of Michigan, UCSF)

Slide Deck, 2023: link

Progress: Deploy Strategies

PPL Technology Research Team Webinars

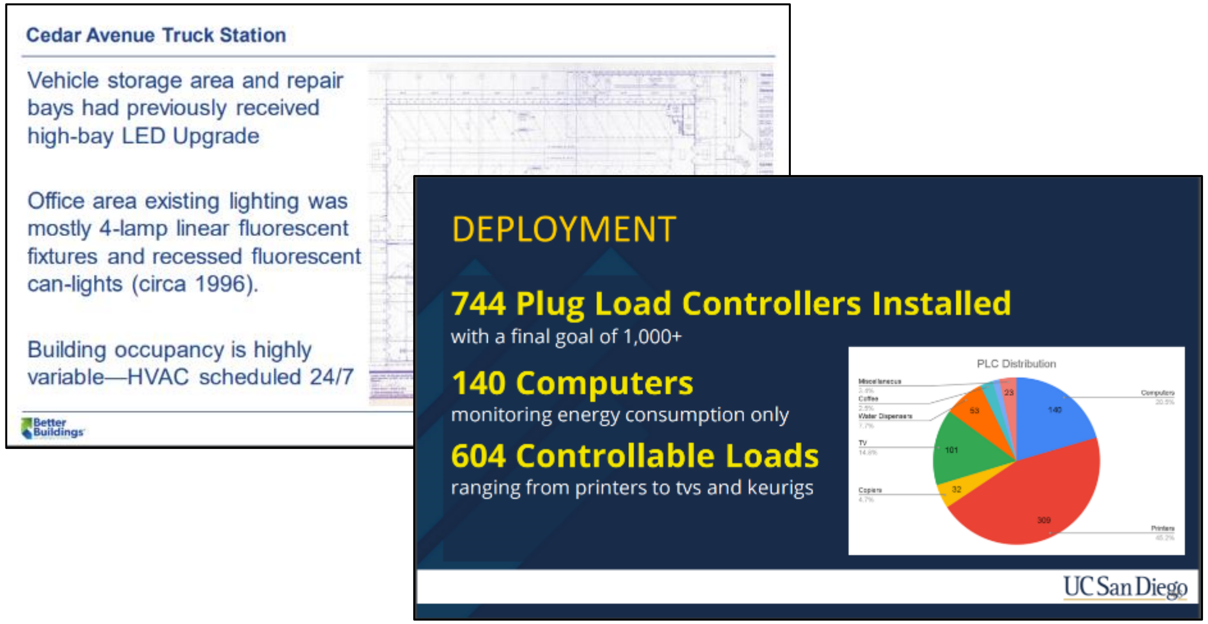
- 2-3 webinars/year
- Typically feature building owners presenting on their plug load management experiences.

Webinar Name	Webinar Date	Live Attendees	On-Demand Views	Total Views
Beyond Energy Efficiency: How Your Device Usage Patterns Affect Energy Consumption	03/17/21	61	420	481
Getting to Net Zero Energy Through Strategic Building Operations and Plug Load Management	05/25/21	68	619	687
No Purchase Necessary: Low to No Cost Plug Load Management Strategies	12/08/21	49	308	357
Better Together: Integrating Plug Load Management into Lighting and Building Management Systems	03/22/22	74	377	451
Trust the Process: Strategies for Reducing Larger Commercial Building Plug and Process Loads	02/9/23	46	103	149

Recent Technology Research Team Webinars

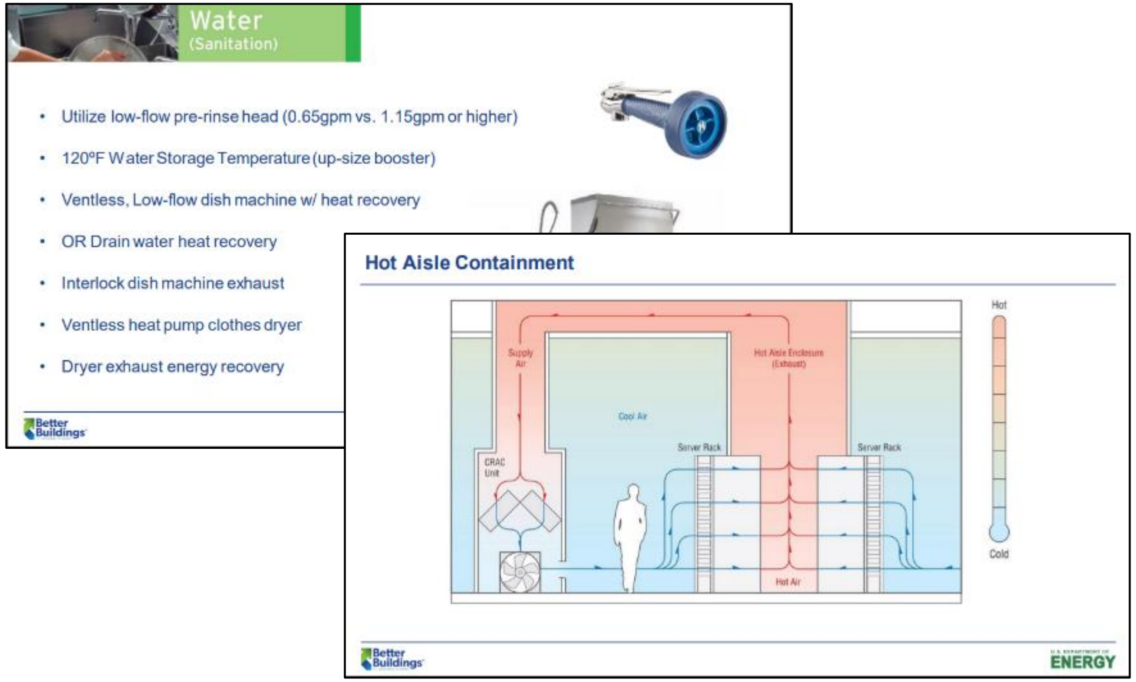
Better Together: Integrating Plug Load Management into Lighting and Building Management Systems

Date: 3/22/2022
Attendance: 74
On-Demand Views: 377
Presenters: Axel Pearson, PNNL; Mark Moehlenbrock, Minnesota Department of Transportation; Dr. Jan Kleissl and Keaton Chia, University of California San Diego
Access the recording and slides here



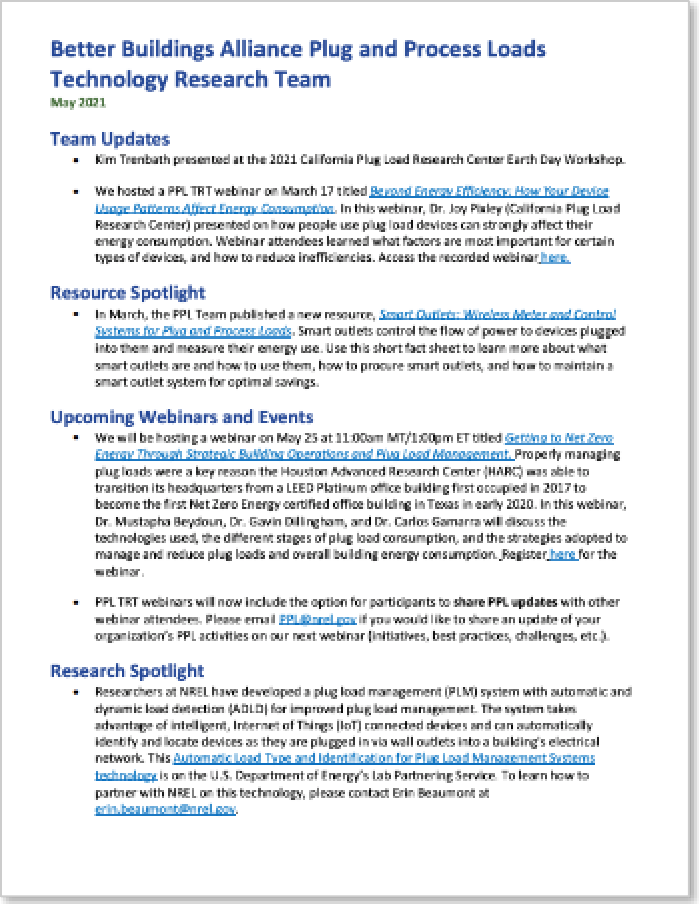
Trust the Process: Strategies for Reducing Larger Commercial Building Plug and Process Loads

Date: 2/9/2023
Attendance: 46
On-Demand Views: 103
Presenters: Brian Turner, CMTA; John Sasser, Sabey Data Centers
Access the recording and slides here



Resources for BBA Partners

Quarterly Email Updates



Better Buildings Alliance Plug and Process Loads Technology Research Team

May 2021

Team Updates

- Kim Trenbath presented at the 2021 California Plug Load Research Center Earth Day Workshop.
- We hosted a PPL TRT webinar on March 17 titled *Beyond Energy Efficiency: How Your Device Usage Patterns Affect Energy Consumption*. In this webinar, Dr. Joy Pixley (California Plug Load Research Center) presented on how people use plug load devices can strongly affect their energy consumption. Webinar attendees learned what factors are most important for certain types of devices, and how to reduce inefficiencies. Access the recorded webinar here.

Resource Spotlight

- In March, the PPL Team published a new resource, *Smart Outlets: Wireless Meter and Control Systems for Plug and Process Loads*. Smart outlets control the flow of power to devices plugged into them and measure their energy use. Use this short fact sheet to learn more about what smart outlets are and how to use them, how to procure smart outlets, and how to maintain a smart outlet system for optimal savings.

Upcoming Webinars and Events

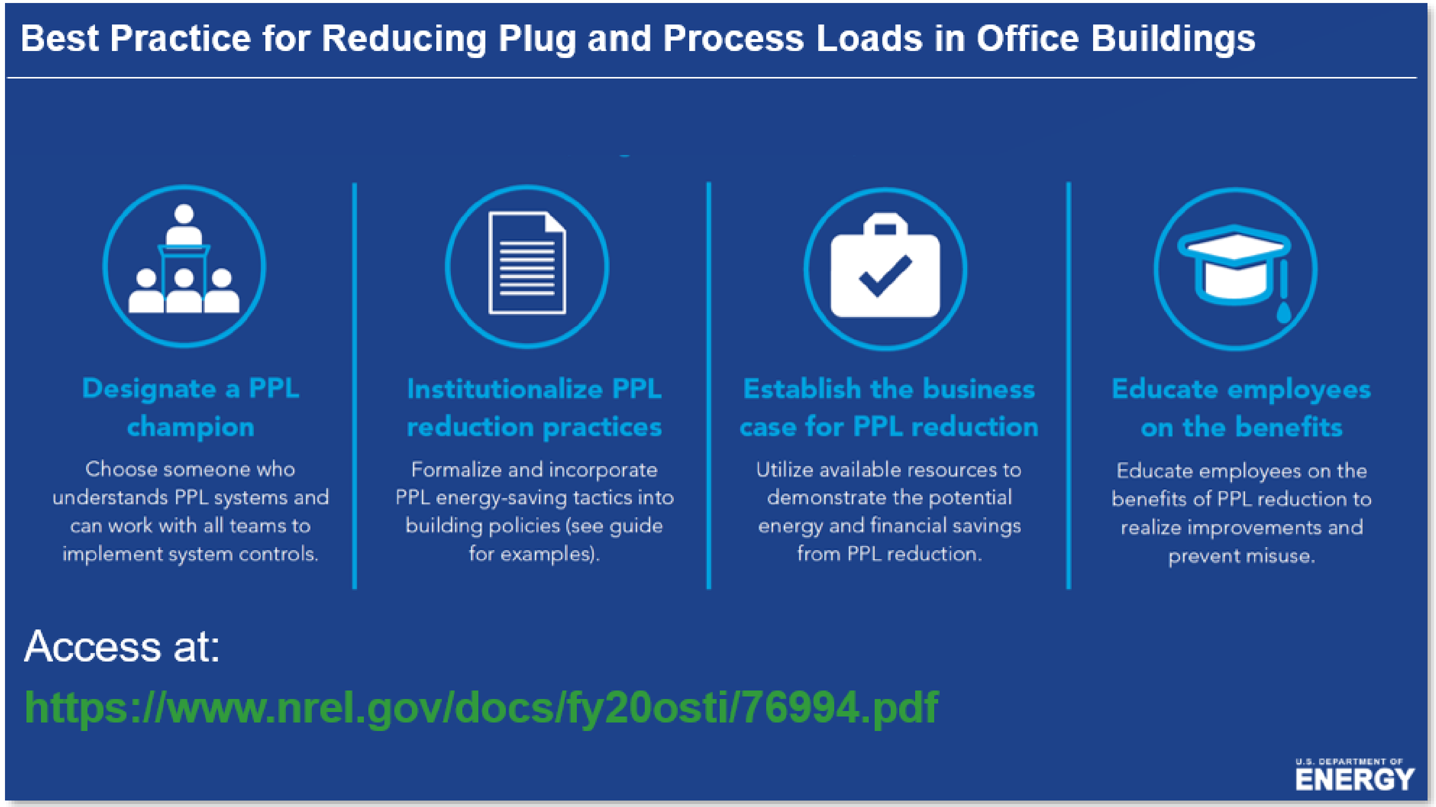
- We will be hosting a webinar on May 25 at 11:00am MT/1:00pm ET titled *Getting to Net Zero Energy Through Strategic Building Operations and Plug Load Management.* Properly managing plug loads were a key reason the Houston Advanced Research Center (HARC) was able to transition its headquarters from a LEED Platinum office building first occupied in 2017 to become the first Net Zero Energy certified office building in Texas in early 2020. In this webinar, Dr. Mustapha Beydoun, Dr. Gavin Dillingham, and Dr. Carlos Gamarra will discuss the technologies used, the different stages of plug load consumption, and the strategies adopted to manage and reduce plug loads and overall building energy consumption. Register here for the webinar.
- PPL TRT webinars will now include the option for participants to **share PPL updates** with other webinar attendees. Please email PPL@nrel.gov if you would like to share an update of your organization's PPL activities on our next webinar (initiatives, best practices, challenges, etc.).

Research Spotlight

- Researchers at NREL have developed a plug load management (PLM) system with automatic and dynamic load detection (ADLD) for improved plug load management. The system takes advantage of intelligent, Internet of Things (IoT) connected devices and can automatically identify and locate devices as they are plugged in via wall outlets into a building's electrical network. This Automatic Load Type and Identification for Plug Load Management Systems technology is on the U.S. Department of Energy's Lab Partnering Service. To learn how to partner with NREL on this technology, please contact Erin Beaumont at erin.beaumont@nrel.gov.

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

Blogs



https://betterbuildingssolutioncenter.energy.gov/beat-blog?f%5B0%5D=field_tags%3A1370

Channels for Deploying Strategies

One-on-One Calls

- Provide technical assistance to BBA partners and design firms
- Learn about state of PPL control technologies from manufacturers

The PPL Team presents at the 2022 CalPlug Workshop.

Technical Presentations

- Conferences and Workshops
    - California Plug Load Research Center
    - American Society for Healthcare Engineering
    - U.S. DOE Miscellaneous Electric Loads Round Table
    - ACEEE Summer Study for Efficiency in Buildings
- BBA Sector Calls
    - Low Carbon Pilot Peer Exchange
    - Healthcare
    - Retail, Food Service, and Grocery
    - Commercial Real Estate

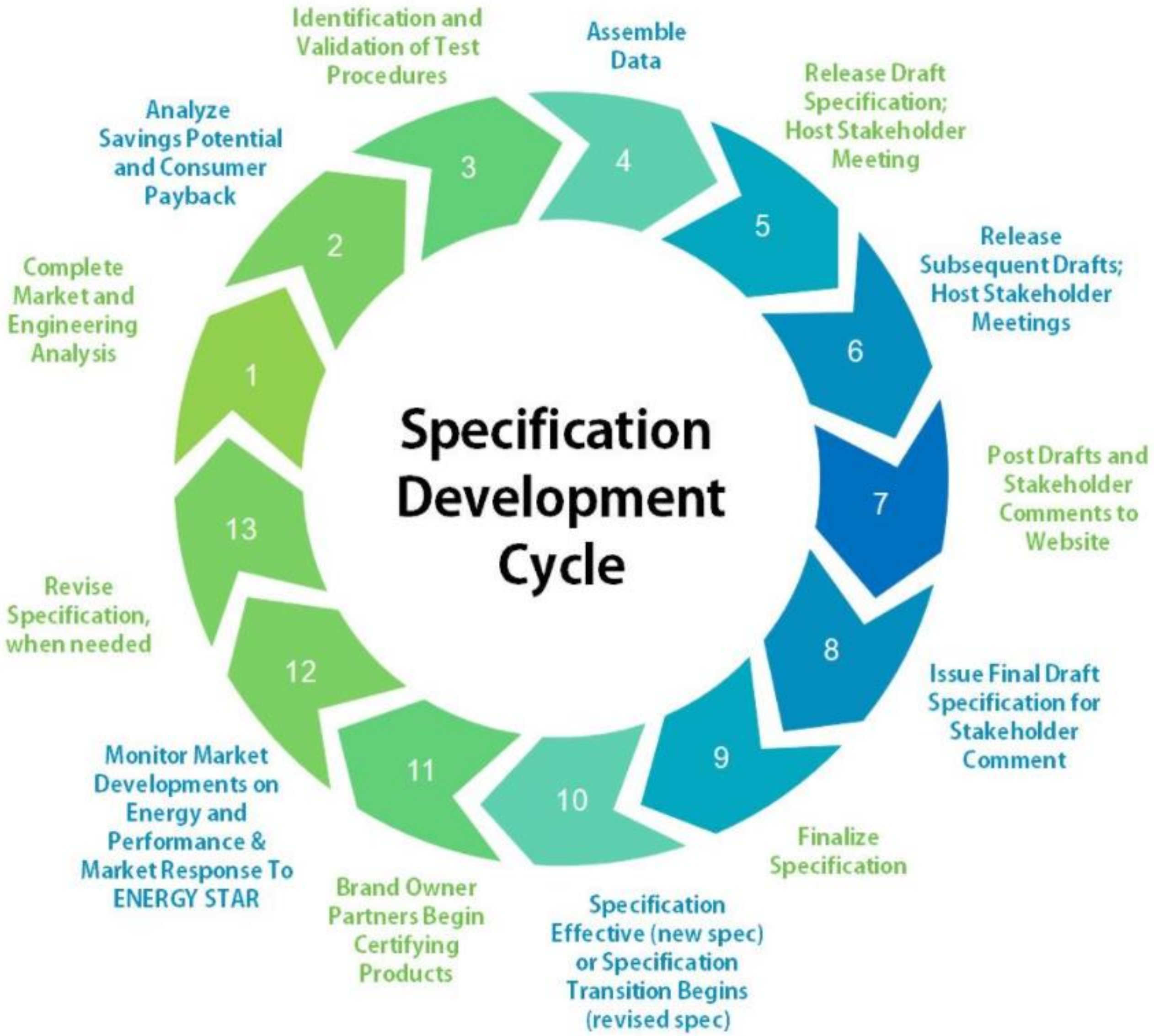
Future Work

Future Work: Resources for Building Owners

- **Webinars**
  - Topic: PPL energy consumption in commercial buildings
    - This webinar highlights PPL energy consumption and load profile research and provides an overview the PPL energy intensity.
    - Estimated Date: June 2023
  - Topic: Medical Imaging Equipment Metering
    - Healthcare building owners will share their experiences and lessons learned on the field measurements of medical imaging equipment in their facilities.
    - Estimated Date: August 1, 2023
- **Publications**
  - Fact Sheet: Medical Imaging Equipment Energy Efficiency - This 2-4 page document will give an overview of MIE energy use in healthcare buildings.
  - Fact Sheet: Seamlessly using enterprise-wide computer power management.

Future Work: DOE Medical Imaging Equipment (MIE) Technical Assistance

- **Continue working with healthcare partners (UC Davis Health, University of Michigan Medicine) for**
  - Selecting best possible MIE options for field measurements
  - Developing submetering plan for conducting MIE measurements in field to inform EPA ENERGY STAR test procedure
  - Analyzing the collected data
  - Possible publication for distribution of the collected data

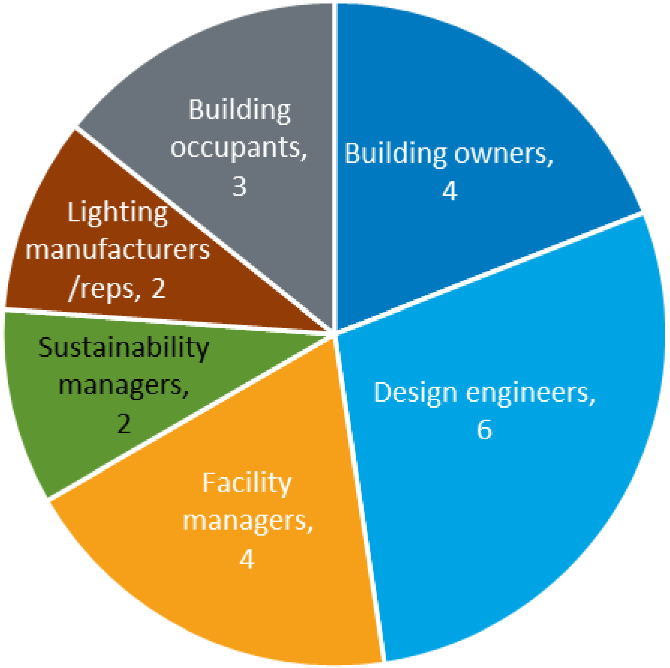


Future Work: Pathways to PPL Efficiency and Control

Investigate barriers and drivers for PPL efficiency and control to identify pathways for achieving uptake.

Data Sources

- 21 stakeholder interviews
- Nexus Labs member workshop



Outcomes

- Identification of market pathways (strategies or technologies) for achieving control of commercial building PPLs

Conclusion

PPLs are a large part of whole-building energy use and a multifaceted challenge to assess, reduce, and control.

The PPL Team is addressing this challenge through R&D, market transformation, and stakeholder engagement efforts to equitably decarbonize buildings and assist BTO to achieve its climate mitigation goals.

Thank You

National Renewable Energy Laboratory
Dr. Kim Trenbath, Innovation Lead, Systems Technology R&D
720-434-9508 kim.Trenbath@nrel.gov
2.2.2.91 NREL – Systems Technology R&D

Supporting Slides

Project Execution

	FY2023			
Planned budget	$394,000			
Spent budget	$138,950			
	Q1	Q2	Q3	Q4
Past Work				
Q1 Milestone: Biannual BBA PPL TRT Call				
Q2 Milestone: Quarterly Strategic Working Group Calls				
Q3 Milestone: Quarterly Email Updates to PPL TRT Mail List				
Q4 Milestone: Medical Imaging Equipment PowerPoint				
Q1 Milestone: Process Loads Resource				
Current/Future Work				
Q3 Milestone: Biannual BBA PPL TRT Call				
Q4 Milestone: Quarterly Strategic Working Group Calls				

Significant Milestones Timeline

Aug. 2017

NREL publishes EMIS/PPL Landscaping Study identifying the following priority research areas:

1. Integrating PPL data into EMIS platforms
2. Interoperability of PPL data with other building end-use data
3. Development and testing of automatic PPL controls.

NREL installs smart outlets for field validation.

June 2019

NREL publishes paper using smart outlet data: Device-level plug load disaggregation in a zero energy office building and opportunities for energy savings

Dec. 2019

NREL publishes paper using smart outlet data: Device-level plug load disaggregation in a zero energy office building and opportunities for energy savings

Aug. 2020

NREL publishes an ACEEE Summer Study paper on Emerging Technologies for Improved Plug Load Management Systems.

Nov. 2020

NREL and UCSD win a California Energy Commission Grant, Smart Plug Load Controls Integrated with Building Energy Management Systems.

Sep. 2021

NREL publishes conference paper on novel PLM system (ATLIS).

NREL releases Smart Outlet Fact Sheet, two resources on assessing and reducing PPL in commercial buildings, and a blog on PPL utility incentives.

Mar. 2022

NREL publishes ILC Case Study on ARC/lighting integration and hosts the building owners on our TRT Call.

NREL presents Medical Imaging Equipment Technical Information to DOE and EPA.

Jul. 2022

NREL presents two presentation at the U.S. DOE's MELS Roundtable.

NREL is part of a team that presents Energy Efficient Medical Equipment: Market Demand and Technical Solutions at the ASHE annual conference.

Aug. 2022

NREL holds informal PPL session at the 2022 ACEEE Summer Study.

NREL and UCSD submit findings to IEEE Grid Edge smart outlet and BAS integration.

Sep. 2022

NREL is issued a U.S. Patent Plug Load Management with Load Identification

NREL publishes the ARC Fact Sheet in collaboration with NEMA.

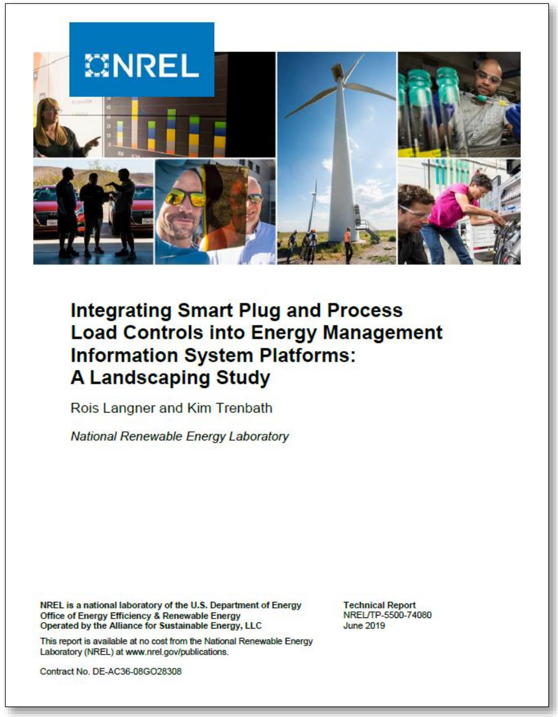
Integrating Smart Plug and Process Load Controls into Energy Management Information System Platforms: A Landscaping Study

OBJECTIVE: Outline emerging PPL technologies, characteristics necessary for successful integration into EMIS platforms, and research questions DOE can pursue to rapidly advance state of the art.

IMPACT

- Guided the work of PPL Team over last several years.
- Guided other entities. CEC used the Landscaping Study to inform their applied R&D and technology demonstration and deployment projects that advance innovative technologies for controlling plug loads.
- Identified priority research areas: (1) Integrating PPL data into EMIS platforms (2) Interoperability of PPL data with other building end-use data (3) Development and testing of automatic PPL controls.
- Provided market direction to building owners and manufacturers.

Technical Report, 2019: link



NREL

Integrating Smart Plug and Process Load Controls into Energy Management Information System Platforms: A Landscaping Study

Rois Langner and Kim Trenbath

National Renewable Energy Laboratory

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-5500-74080
June 2019

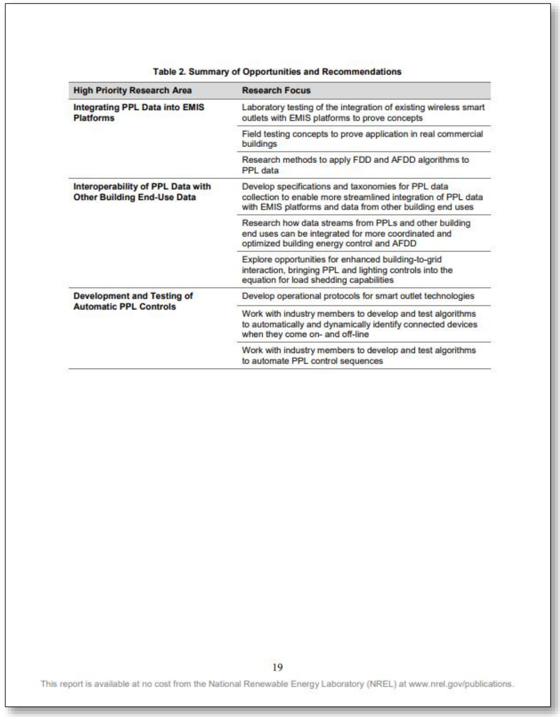


Table 2. Summary of Opportunities and Recommendations

High Priority Research Area	Research Focus
Integrating PPL Data into EMIS Platforms	Laboratory testing of the integration of existing wireless smart outlets with EMIS platforms to prove concepts
	Field testing concepts to prove application in real commercial buildings
	Research methods to apply FDD and AFDD algorithms to PPL data
Interoperability of PPL Data with Other Building End-Use Data	Develop specifications and taxonomies for PPL data collection to enable more streamlined integration of PPL data with EMIS platforms and data from other building end uses
	Research how data streams from PPLs and other building end uses can be integrated for more coordinated and optimized building energy control and AFDD
	Explore opportunities for enhanced building-to-grid interaction, bringing PPL and lighting controls into the equation for load shedding capabilities
Development and Testing of Automatic PPL Controls	Develop operational protocols for smart outlet technologies
	Work with industry members to develop and test algorithms to automatically and dynamically identify connected devices when they come on- and off-line
	Work with industry members to develop and test algorithms to automate PPL control sequences

19

This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

KEY STAKEHOLDERS

Informed by survey of PPL control technologies, research papers on smart building technologies for PPL, and smart buildings roundtable.

Device-level plug load disaggregation in a zero energy office building and opportunities for energy savings

RESEARCH QUESTIONS: How can individual device monitoring and building-level submeters be used to develop a disaggregated breakdown of plug loads in an office building? What insights can be gained from disaggregation?

IMPACT

- Method for developing a disaggregated model of an office building's plug loads that utilizes power data from a small portion of monitored devices and a device inventory.
- Disaggregation allows for targeted savings. Model identified that AV controllers account for a significant portion of the unoccupied load. Provided case study for a more efficient method for monitoring plug load energy use.

Journal Article, 2019: link
Fact Sheet, 2020: link

Emerging Technologies for Plug Load Management (PLM)

RESEARCH QUESTIONS: What is the current state of learning behavior algorithms (LBA) and automatic and dynamic (ADLD) technologies in PLM systems? What are the technology challenges and market barriers for LBA and ADLD? What are the drivers and opportunities for the further development of these technologies?

IMPACT

- Drove development of PLM technologies, internally and externally.
- Characterized two emerging PLM technologies.
- LBA reduce human impact in a PLM system and can predict anomalies. LBA could encourage integration of plug load data with data from other sources.
- ADLD offers a plug-and-play system and easy installation that saves time.
- R&D needed: scaling for large commercial buildings, achieving economies of scale, and addressing cybersecurity.

Conference Paper, 2020: link
Fact Sheet, 2020: link

Emerging Technologies for Improved Plug Load Management Systems: Learning Behavior Algorithms and Automatic and Dynamic Load Detection

Kim Trenbath, Bennett Doherty, National Renewable Energy Laboratory
Katie Vrabel, Carly Burke, Waypoint Energy

ABSTRACT

Plug loads are responsible for a significant portion of the energy consumed in commercial buildings, yet their distributed and ever-changing nature makes them one of the most challenging building end uses to manage. Plug load management systems exist today that use smart plugs to meter and control devices at the outlet level, but their uptake has been relatively slow in part because of the significant labor required for installation and maintenance. Learning behavior algorithms and automatic and dynamic load detection are two technology areas that could accelerate the adoption of plug load management systems by reducing these labor demands and providing additional energy efficiency and nonenergy benefits. Learning behavior algorithms learn occupant behavior and adjust plug load management systems accordingly, allowing for the automatic creation of optimized control schedules. Automatic and dynamic load detection allows a plug load management system to identify devices as they are plugged in to a building and keeps the system up to date as devices are moved throughout a building. In this paper, we present our findings on the current state of these two technologies based on a review of existing research and patents as well as a series of interviews with companies working in the plug load space. We found that no commercialized solutions currently exist for these plug load technologies, and more work is needed to bring them to market. In addition, we summarize our findings related to the technology challenges and market barriers, drivers, and opportunities for these technologies moving forward.

Introduction

Plug and process loads (PPLs) represent more than 40% of the total energy use in U.S. commercial buildings and this percentage is projected to increase during the next 30 years (EIA 2020). PPLs are challenging to manage and control given that they are distributed throughout a building and can consist of numerous loads, many of which are relatively small. To help with PPL reductions, building standards (e.g., California Title 24, ASHRAE 90.1, and the International Energy Conservation Code) are adopting plug load energy management mandates that require a portion of the outlets in a building to be controlled. Controls allow devices to be turned on and off automatically via set schedules or based on occupancy, reducing equipment power consumption when not in use. Controlling individual pieces of equipment can yield up to 30% savings on PPL energy consumption (Langner and Christensen 2018).

Currently, there are solutions available that offer both PPL control and metering capabilities down to the socket level. Often referred to as "smart plugs," the hardware in these technologies collects power consumption data from individual devices and can turn devices on or off by controlling the flow of electricity to the device. In some cases, this is accomplished with hardware located between the outlet and the equipment plug; in others, the hardware is integrated into the outlet itself. These smart plugs are often part of a greater plug load management (PLM)

©2020 Summer Study on Energy Efficiency in Buildings 3-409

Better Buildings
Fact Sheet: Emerging Plug Load Management Technologies that Save Energy and Time
BETTER BUILDINGS ALLIANCE
Introduction
What is the current state of LBA & ADLD technologies in PLM systems?
Learning Behavior Algorithms
Automatic and Dynamic Load Detection
Conclusions
ENERGY

KEY STAKEHOLDERS

Engaged with PPL control technology manufacturers to determine barriers and opportunities for cutting-edge PLM technologies.

Utility Incentives

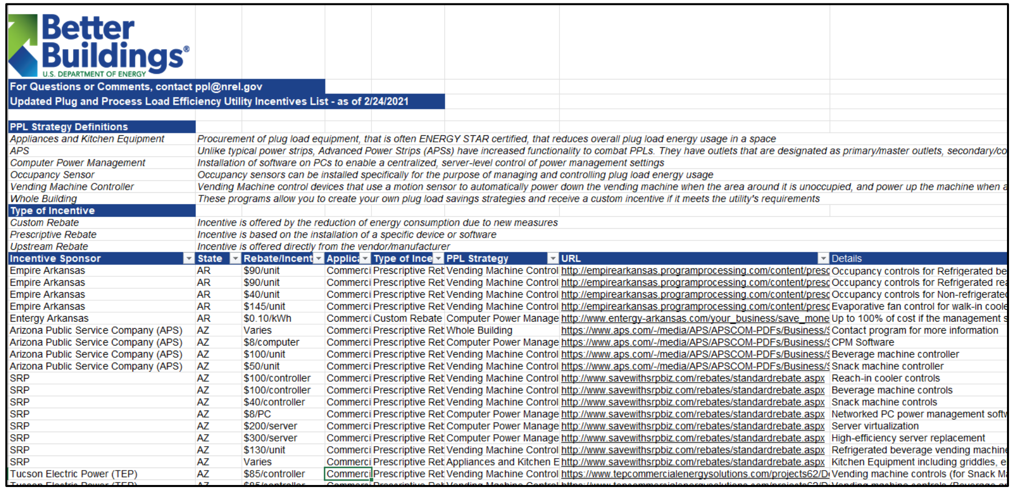
OBJECTIVE:

Provide comprehensive list of PPL utility incentives for building owners.

IMPACT

- Encourage adoption of PPL control and reduction technologies by providing information about utility incentives around the country.
- In past, list published annually.

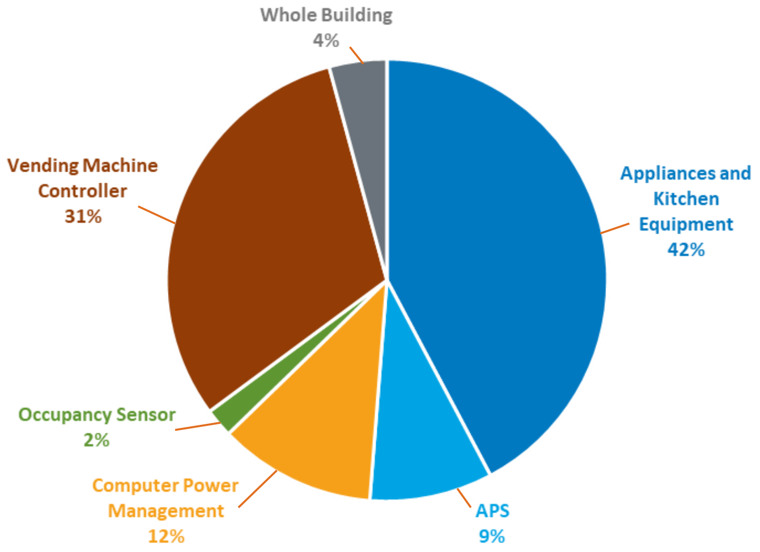
Incentive List, 2022: link
Beat Blog Post, 2021: link



For Questions or Comments, contact ppl@nrel.gov
Updated Plug and Process Load Efficiency Utility Incentives List - as of 2/24/2021

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/master outlets, secondary/co*
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 power up the machine when a*
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/Incent	Applic	Type of Ince	PPL Strategy	URL	Details
Empire Arkansas	AR	$90/unit	Commerci	Prescriptive Ret	Vending Machine Control	http://empirearkansas.programprocessing.com/content/presc	Occupancy controls for Refrigerated be
Empire Arkansas	AR	$90/unit	Commerci	Prescriptive Ret	Vending Machine Control	http://empirearkansas.programprocessing.com/content/presc	Occupancy controls for Refrigerated re
Empire Arkansas	AR	$40/unit	Commerci	Prescriptive Ret	Vending Machine Control	http://empirearkansas.programprocessing.com/content/presc	Occupancy controls for Non-refrigerated
Empire Arkansas	AR	$145/unit	Commerci	Prescriptive Ret	Vending Machine Control	http://empirearkansas.programprocessing.com/content/presc	Evaporative fan control for walk-in coole
Entergy Arkansas	AR	$0.10/kWh	Commerci	Custom Rebate	Computer Power Manage	http://www.entergy-arkansas.com/your_business/save_mone	Up to 100% of cost if the management s
Arizona Public Service Company (APS)	AZ	Varies	Commerci	Prescriptive Ret	Whole Building	https://www.aps.com/-/media/APS/APSCOM-PDFs/Business/	Contact program for more information
Arizona Public Service Company (APS)	AZ	$8/computer	Commerci	Prescriptive Ret	Computer Power Manage	https://www.aps.com/-/media/APS/APSCOM-PDFs/Business/	CPM Software
Arizona Public Service Company (APS)	AZ	$100/unit	Commerci	Prescriptive Ret	Vending Machine Control	https://www.aps.com/-/media/APS/APSCOM-PDFs/Business/	Beverage machine controller
Arizona Public Service Company (APS)	AZ	$50/unit	Commerci	Prescriptive Ret	Vending Machine Control	https://www.aps.com/-/media/APS/APSCOM-PDFs/Business/	Snack machine controller
SRP	AZ	$100/controller	Commerci	Prescriptive Ret	Vending Machine Control	http://www.savewithsrpbiz.com/rebates/standardrebate.aspx	Reach-in cooler controls
SRP	AZ	$100/controller	Commerci	Prescriptive Ret	Vending Machine Control	http://www.savewithsrpbiz.com/rebates/standardrebate.aspx	Beverage machine controls
SRP	AZ	$40/controller	Commerci	Prescriptive Ret	Vending Machine Control	http://www.savewithsrpbiz.com/rebates/standardrebate.aspx	Snack machine controls
SRP	AZ	$8/PC	Commerci	Prescriptive Ret	Computer Power Manage	http://www.savewithsrpbiz.com/rebates/standardrebate.aspx	Networked PC power management softw
SRP	AZ	$200/server	Commerci	Prescriptive Ret	Computer Power Manage	http://www.savewithsrpbiz.com/rebates/standardrebate.aspx	Server virtualization
SRP	AZ	$300/server	Commerci	Prescriptive Ret	Computer Power Manage	http://www.savewithsrpbiz.com/rebates/standardrebate.aspx	High-efficiency server replacement
SRP	AZ	$130/unit	Commerci	Prescriptive Ret	Vending Machine Control	http://www.savewithsrpbiz.com/rebates/standardrebate.aspx	Refrigerated beverage vending machine
SRP	AZ	Varies	Commerci	Prescriptive Ret	Appliances and Kitchen E	http://www.savewithsrpbiz.com/rebates/standardrebate.aspx	Kitchen Equipment including griddles, e
Tucson Electric Power (TEP)	AZ	$85/controller	Commerci	Prescriptive Ret	Vending Machine Control	https://www.tepcommercialenergysolutions.com/projects62/D	Vending machine controls (for Snack Ma



Integrated Controls for Plug Loads and Lighting Systems Case Study

OBJECTIVE: The focus of this case study is to highlight the strategies used at Cedar Avenue truck station for integrating plug load and lighting systems.

IMPACT

- Communicated strategies that other buildings can learn from through a written case student and a webinar.
- Promoted PPL control strategies: having a main point-of-contact for all stakeholders, providing occupant user guides and signage, involving the information technology department, make sure controlled device is in the occupancy zone.

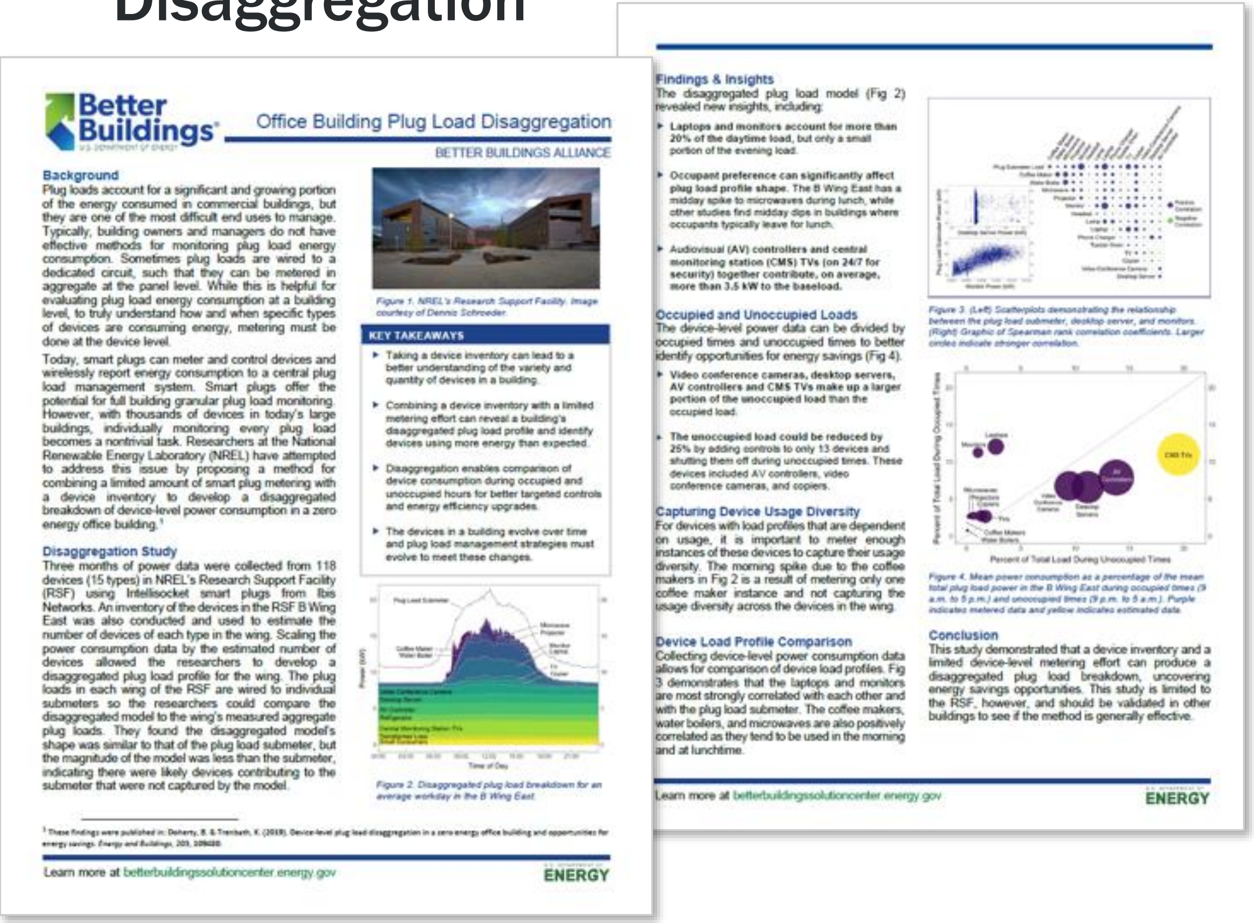
Case Study, 2022: link
TRT Webinar, 2022: link

KEY PARTNERS

Minnesota Department of Transportation (MnDOT), Integrated Lighting Campaign (ILC), Slipstream, CREE

Resources for BBA Partners: Fact Sheets

Office Building Plug Load Disaggregation



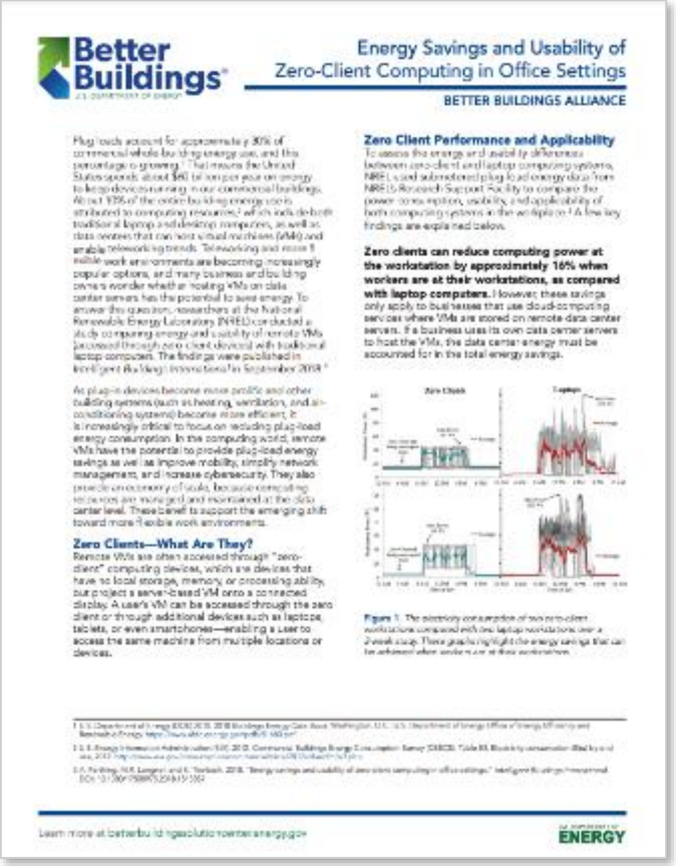
https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/PPL_Disaggregation_NREL.pdf

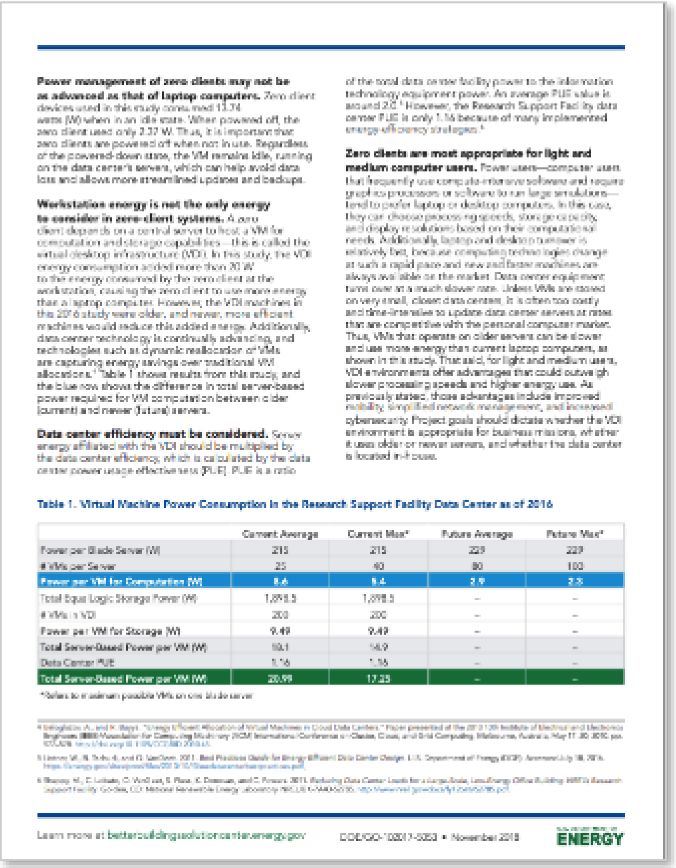
Emerging Technologies for Plug Load Management

https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/BBA_Emerging_PlugLoad_Mgmt_FactSheet.pdf

Resources for BBA Partners: Fact Sheets

Zero Client Computing





	Current Average	Current Max*	Future Average	Future Max*
Power per Blade Server (W)	215	215	229	229
# VMs per Server	25	40	80	100
Power per VM for Computation (W)	8.6	5.4	2.9	2.3
Total Equal Logic Storage Power (W)	1,898.5	1,898.5	–	–
# VMs in VDI	200	200	–	–
Power per VM for Storage (W)	9.49	9.49	–	–
Total Server-Based Power per VM (W)	18.1	14.9	–	–
Data Center PUE	1.16	1.16	–	–
Total Server-Based Power per VM (W)	20.99	17.25	–	–

*Refers to maximum possible VMs on one blade server

https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/BBA_Zero_Client_Computing_Case_Study.pdf

FY19 & 20 Technology Research Team Webinars

Plug Load Management System Field Study: Wireless Meters and Controls

Date: 3/20/2019
Attendance: 28
On-Demand Views: 106
Presenters: Kim Trenbath, NREL; Alicen Kandt, NREL
Link:
https://betterbuildingssolutioncenter.energy.gov/webinars/plug-load-management-system-field-study-wireless-meters-and-controls

Zero Client Computing and Set Top Box Voluntary Agreements

Date: 11/13/2019
Attendance: 23
On-Demand Views: 75
Presenters: Amanda Farthing, University of Michigan; Jennifer Amann, American Council for an Energy-Efficient Economy
Link:
https://betterbuildingssolutioncenter.energy.gov/webinars/zero-client-computing-and-set-top-box-voluntary-agreements

How much energy are your devices consuming? Plug load disaggregation and the future of device energy savings

Date: 1/22/2020
Attendance: 47
On-Demand Views: 403
Presenters: Bennett Doherty, NREL; Bruce Nordman, LBL
Link:
https://betterbuildingssolutioncenter.energy.gov/webinars/how-much-energy-are-your-devices-consuming-plug-load-disaggregation-and-future-device

FY20 Technology Research Team Webinars

Automatic Receptacle Controls: Adjusting to New Code Requirements for Plug Load Controls

Date: 4/30/2020
Attendance: 57
On-Demand Views: 622
Presenters: Harold Jepsen, Legrand; Kelly Cunningham & Marisa Lee, Pacific Gas & Electric

Link:
https://betterbuildingssolutioncenter.energy.gov/webinars/automatic-receptacle-controls-adjusting-new-code-requirements-plug-load-controls

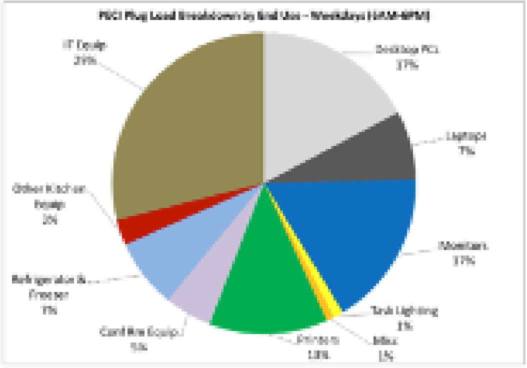
Control marked receptacle

Wireless controlled receptacle

Case in Point: Oregon’s Recent Efforts to Reduce Plug Load Energy Consumption

Date: 7/22/2020
Attendance: 181
On-Demand-Views: 402
Presenters: Dave Wortman, Statewide Sustainability Officer Oregon Department of Administrative Services; Stephanie Kruse, Facilities Engineer, Oregon Department of Energy

Link:
https://betterbuildingssolutioncenter.energy.gov/webinars/case-point-oregon%E2%80%99s-recent-efforts-reduce-plug-load-energy-consumption



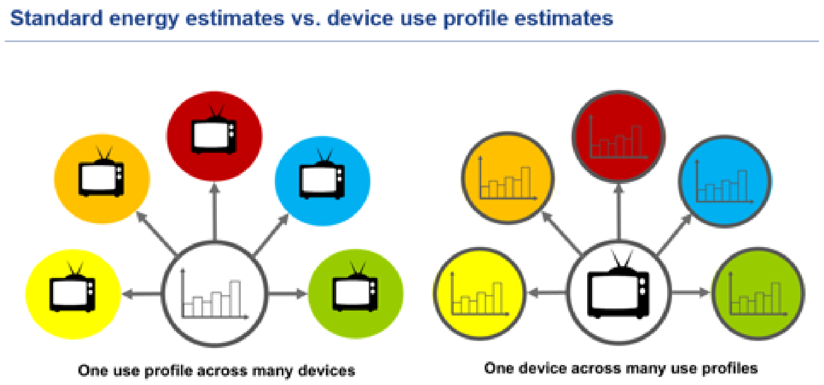
Plug load breakdown in small office in Portland, Oregon.

FY21 Technology Research Team Webinars

Beyond Energy Efficiency: How Your Device Usage Patterns Affect Energy Consumption

Date: 3/17/2021
Attendance: 61
On-Demand Views: 420
Presenters: Felipe Leon, PNNL; Joy Pixley, University of California, Irvine

Link:
https://betterbuildingssolutioncenter.energy.gov/webinars/beyond-energy-efficiency-how-your-device-usage-patterns-affect-energy-consumption



Getting to Net Zero Energy Through Strategic Building Operations and Plug Load Management

Date: 5/25/2021
Attendance: 68
On-Demand Views: 619
Presenters: Mustapha Beydoun, Houston Advanced Research Center; Gavin Dillingham, Houston Advanced Research Center; Carlos Gamarra, Houston Advanced Research Center

Link:
https://betterbuildingssolutioncenter.energy.gov/webinars/getting-net-zero-energy-through-strategic-building-operations-and-plug-load-management

Future Work: Additional General Efforts

- **Connect building owners, manufacturers, building designers, researchers, and other stakeholders**
  - Achieve “low hanging fruit” energy savings by deploying strategies.
  - Help develop equitable and affordable solutions by communicating needs of small building owners to technology developers.
- **Support work on integrated controls**
  - Communicate case studies of integrated projects
  - Include affordability as a key as design criteria for technology solutions
- **Continue to work to characterize commercial building PPLs and technology pathways**
  - Support disaggregation studies
  - Market research

Future Work: Automatic Receptacle Control (ARC) Markings

Collaboration with Pacific Northwest National Laboratory

Working to increase uptake of ARC, which are in adopted building codes

NREL Transforming ENERGY

Photo by Dennis Schroeder, NREL 29518

Automatic Receptacle Controls:
What they are and why they should be commonplace in building energy codes

Introduction

Plug loads account for over 16% of commercial building electricity consumption, and are expected to increase to 21.3% by 2050 (EIA 2022). As buildings become more energy efficient through other end uses, such as lighting and HVAC (heating, ventilating, and air conditioning), and as more electric devices are added to buildings, the plug and process load (PPL) portion of building energy use will continue to grow and therefore should be addressed. PPLs, and specifically plug loads, have unique characteristics that can make it challenging to reduce their energy use. For instance, plug-in devices are often left on when not in use, drawing power. They also draw power while in standby mode, and some plug-in devices even continue to draw power when plugged in and turned off, referred to as vampire or parasitic loads. Automatic receptacle controls (ARCs), commonly referred to as plug load control, can help building owners and occupants reduce these plug loads. Therefore, a growing number of states and local jurisdictions are requiring ARCs as part of their commercial building energy codes.

What Are ARCs?

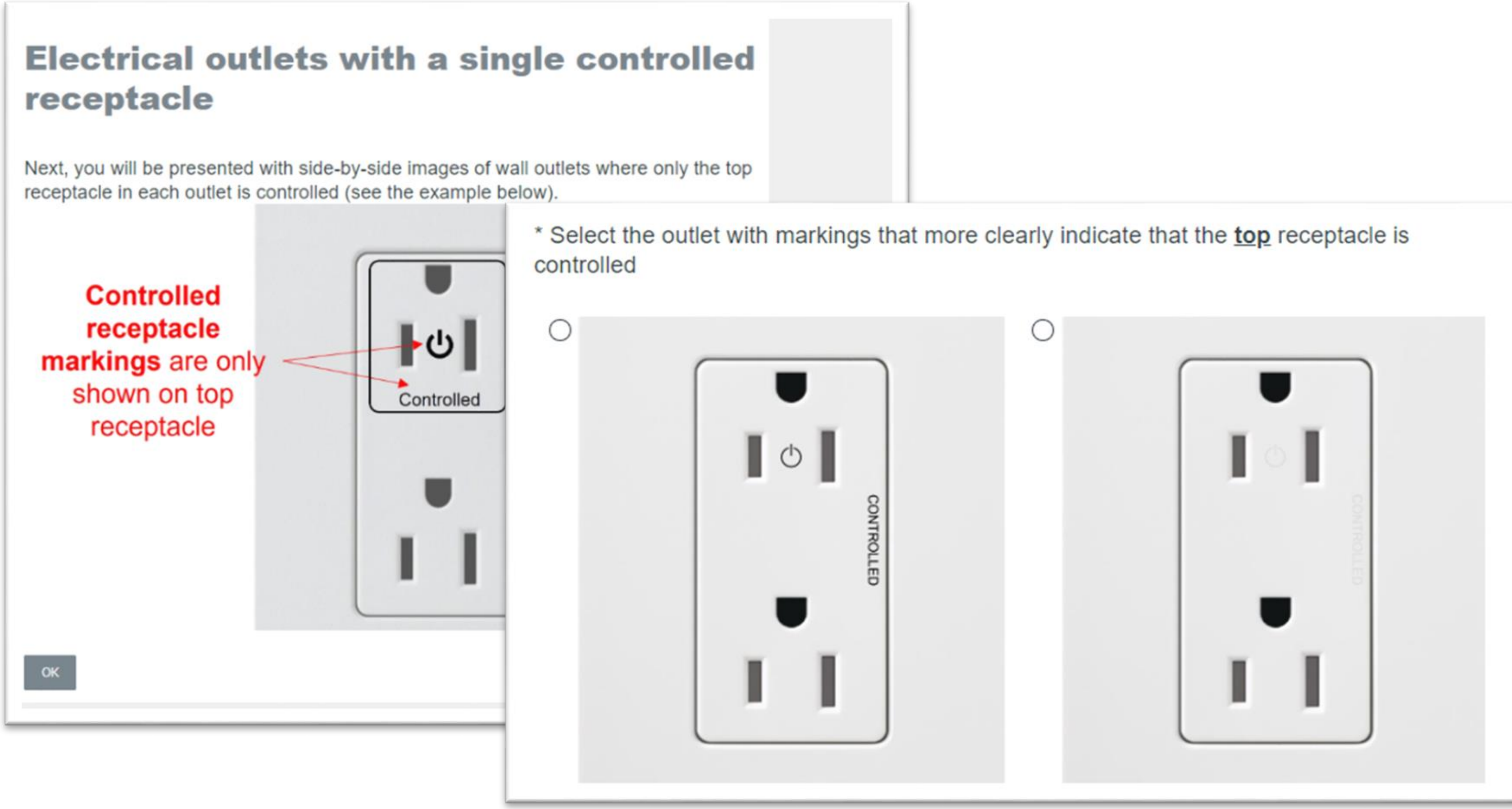
According to the U.S. National Electrical Code (NEC), Section 100, an outlet is a point in an electrical circuit from which current may be drawn. A receptacle is the contact device installed at the outlet and used to connect a plug. ARCs automatically turn off power to receptacles using signals from occupancy sensors, control schedules, or other building systems. They are best suited for plug-in devices that only need to be operational when the building is occupied. The load size that can be controlled by ARCs is only limited by the capacity of the circuit and the receptacle rating. Examples of good plug-in device candidates for ARCs are:

- Displays/monitors
- Task/exam lights
- Space heaters
- Table fans
- Radios/speakers
- Printers
- Hot plates
- Coffee makers
- Televisions
- Exercise equipment.

Controller

Switch

Controlled Receptacle



Photos courtesy of PNNL ARC Survey

EERE/BTO goals

The nation's ambitious climate mitigation goals

Greenhouse gas emissions reductions

50-52% reduction by 2030 vs. 2005 levels

Net-zero emissions economy by 2050

Power system decarbonization

100% carbon pollution-free electricity by 2035

Energy justice

40% of benefits from federal climate and clean energy investments flow to disadvantaged communities

EERE/BTO's vision for a net-zero U.S. building sector by 2050