Assessing and Reducing Plug and Process Loads in Retail Buildings

Introduction

Plug and process loads (PPLs) account for 47% of U.S. commercial building energy consumption (EIA 2020) (see Figure 1). Minimizing these loads is a significant challenge for energy-efficient building design and operation.

Langner and Trenbath (2019) define PPLs as all plug-in and hardwired loads in a building that are not associated with heating, ventilating, and air conditioning (HVAC), lighting, water heating, or other major equipment needed for basic building operation. This includes all plug-in equipment and appliances, as well as processes for cooking, computing, and internal transportation. The percentage of total building energy use from PPLs is increasing; by 2029, the percentage of PPL energy consumption is anticipated to increase to 51% (EIA 2020). The commercial sector is making strides increasing energy efficiency in other end uses, such as HVAC and lighting, but to continue the trend of reducing whole-building energy consumption, PPLs must be targeted as well.

Retail PPLs present a unique challenge because they can directly generate revenue (e.g., vending machines) or be items for sale (e.g., televisions on display). Figure 2 shows the measured PPL energy use for a large retail building and the potential energy cost savings associated with a 30% PPL reduction (in this example, $40,000 annually).
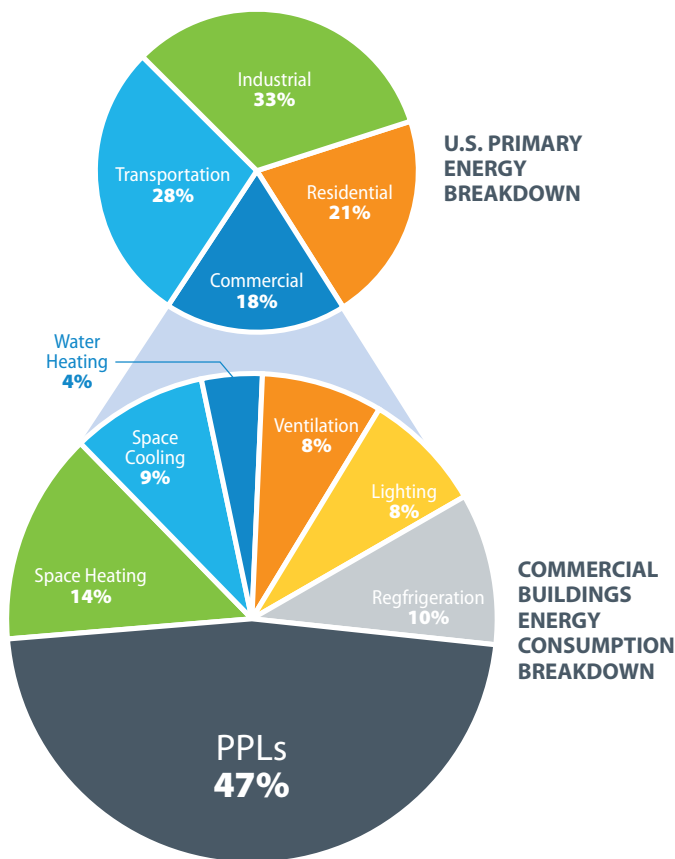

U.S. PRIMARY ENERGY BREAKDOWN

Industrial 33%
Residential 21%
Transportation 28%
Commercial 18%

Water Heating 4%
Space Cooling 9%
Space Heating 14%
Ventilation 8%
Lighting 8%
Refrigeration 10%
PPLs 47%

COMMERCIAL BUILDINGS ENERGY CONSUMPTION BREAKDOWN

Figure 1. Plug and process loads account for 47% of commercial building energy consumption. *Graph by Kristi Maisha, NREL; Data source: EIA (2020)*
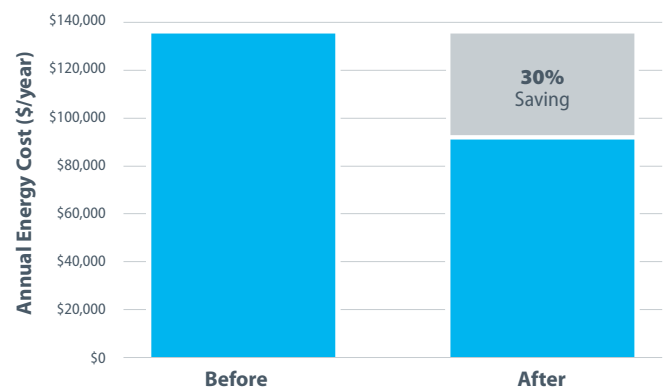

30% Saving

Before   After

Annual Energy Cost ($/year)

Figure 2. A 30% saving in PPL energy use would save $40,000 annually. *Graph by Chad Lobato, NREL*

This "quick start guide" will help building owners and energy managers reduce PPL energy use in their facilities. It packages extensive PPL research into an easy-to-use set of instructions and provides quick references to useful tools, websites, and databases. It is also intended to guide the procurement of new equipment that incorporates strategies and technologies to significantly reduce energy consumption.

Steps for Establishing a Plug and Process Load Reduction Strategy

This section describes the actions that building owners and energy managers should take to develop a PPL control strategy.

Step 1: Establish a Plug and Process Load Champion

The first step in addressing PPLs is to establish a PPL champion (or a team of champions) to initiate and help with the process. This person or team needs to understand basic energy efficiency design strategies and be able to apply cost justifications. They must also have the skills to critically evaluate, address, and influence the building's operations, institutional policies, and procurement processes. PPLs are often specified by multiple parties, so equipment and efficiency strategies are rarely handled by one decision maker. The champion will make sure that all decision makers (such as the information technology and audiovisual teams) are on the same page about PPLs and that their decisions save energy and integrate well with other building systems. The PPL champion must be involved in selecting the control strategy, understand it thoroughly, and monitor the dashboard and energy use data.

PPLs are often treated as an end use to which energy efficiency measures cannot be applied. There are, however, huge opportunities in understanding and managing these loads, and the PPL champion plays an integral role in taking advantage of them.

Step 2: Institutionalize Plug and Process Load Measures

The day-to-day energy efficiency of any building depends largely on the decisions of employees, facility managers, and owners, all of whom play key roles in whole-building energy consumption. Therefore, one key step in reducing PPL energy use is to institutionalize PPL measures. The champion must work with decision makers to incorporate energy saving tactics into building policy, such as purchasing only energy-efficient equipment or requiring the use of low-energy states whenever possible. Particularly, they should work with information technology and audiovisual teams to turn off equipment and schedule technology updates to allow for device shutoff during nonbusiness hours.

It is also crucial that the champion facilitate regular communication between decision makers from these teams and the building facilities staff to maintain the PPL control strategies. For long-term success, the building must have a plan for building occupant turnover. When there are changes in management and employees, steps must be taken to ensure that all occupants are aware of and trained in best practices for using the control strategy.

Step 3: Benchmark Current Equipment and Operations With a Walkthrough

The building benchmarking process provides an estimate for the current status of PPL energy usage in a building. It can help occupants better understand the needs of the building and identify the changes that can be made. The process should begin with a walkthrough of the building to take inventory of all PPL devices. The goal of the walkthrough is to determine device usage, the schedule that the building and devices follow, and device attributes (e.g., how many devices are in the building, the purpose the devices serve for occupants, and the ages of the devices). You can use the NREL PPL reduction workbook to assist in these tasks. The inventory page of the workbook lists the information to be collected during the walkthrough.

If you want a more detailed and precise audit, you can use metering devices to establish the baseline energy usage. For this process, you need a plug load power meter that can wirelessly transmit data collected in 30-second to 1-minute intervals, has an internal clock, and can measure loads from 0 to 1,800 W. After installing the meters, collect plug load data for at least 1 week, longer if possible. A similar benchmarking process is described in Gentile-Polese et al. (2014).

Whether you choose to meter at this stage or not, if the building has sections that are similar, you can use a scalable methodology. This involves auditing one of the sections and then using that information to extrapolate the energy usage of similar sections. See Doherty and Trenbath (2019) for more about this process. The goal is to have the information needed to make decisions about which devices should be targeted and which control strategies are most appropriate.

Step 4: Develop a Business Case for Addressing Plug and Process Loads

To achieve buy-in from all parties involved, the champion must develop a business case that justifies measures to reduce PPLs. Based on the building and occupant needs and PPL energy usage, decide on the PPL reduction goals. For example, you may find that given the number of loads, it would be beneficial to control all plug-in devices and have constant energy-use monitoring. Or you

may find that specific devices are consuming significant energy and target only those devices for controls.

After determining the goals, select the relevant control strategies, many of which are listed in this guide. When considering each strategy, check that the information/data transmission needs match the building's cybersecurity requirements (Langer and Christensen 2018). Control strategies will vary in terms of associated costs, energy savings, and payback periods. The initial business case is based on energy cost savings. Use the PPL calculator in the workbook and the PPL Utility Incentives listed under Policies and Incentives (NREL n.d.-a) to help determine potential financial savings.

Beyond energy savings, there are many nonenergy benefits to incorporating PPL controls. Consolidating loads and reducing the active times of several devices, such as copiers, reduces building air pollutants, improving air quality and the health of building occupants. Constant data production exposes the appliances that are nearing failure or performing incorrectly, allowing for timely maintenance and repairs. The data collection also allows for asset management and occupancy monitoring. You can better understand how the building is being used, which locations in the building are used the most, what equipment should or should not be purchased, and how the occupants behave. PPL reduction strategies can improve whole building functionality and the business case can clearly demonstrate how.

General Plug and Process Load Reduction Strategies

Refer to the Decision Guides for PPL Controls (NREL n.d.-b) to view several strategies for reducing PPL energy usage that do not require infrastructure or system changes and can be implemented along with control strategies to maximize energy savings. Some of these strategies include:

- **Replace inefficient appliances.** Older models can use more energy, so replacing them with their ENERGY STAR®- (ENERGY STAR n.d.) or EPEAT- (EPEAT n.d.) approved equivalent can provide energy savings.

- **Incorporate low power/power off settings.** Many devices have sleep settings or can be manually powered off without affecting the building functionality—computers, for example.

- **Consolidate loads.** Replace redundant loads with one larger load, such as purchasing a large shared printer rather than having individual printers.

- **Time software updates.** Ensure that updates occur at times close to business hours to allow equipment to be shut off during nonbusiness hours.

Plug and Process Load Education and Awareness

A crucial step in reducing PPL energy use is to facilitate employee education and promote employee awareness of efficiency measures and best practices. In order to take full advantage of all the benefits offered by plug load meters and controls, employees must be aware of what PPL reduction strategies have been implemented in the building, including:

- How the system (meters, controls, power strip) will help save energy in the office
- What actions need to be taken to save energy (putting appliances in low power mode, monitoring the dashboard, etc.)
- How to reset or adjust the controls in the event of a malfunction or schedule change.

Case studies have shown that without the education and awareness, there is a high likelihood for employees to unplug or choose to forgo the control system (Metzger et al. 2012; Kandt and Langner 2019). To realize the full potential and savings of PPL meters and controls, this step is necessary and should be reinforced throughout the lifetime of the control system. Figure 3 is an example of a sticker that could be placed on computers and monitors to remind employees to turn off their equipment when it is not being used. Other employee awareness strategies include:

- Training
- Emails
- Competitions among employees
- Signage
- Videos
- Periodic reminders or updates.

Figure 3. Sticker used at NREL to promote awareness.
Illustration by Marjorie Schott, NREL

Control Strategies

Wireless Meter and Control Systems

Wireless meter and control systems involve a system of smart outlets that are plugged into existing outlets and measure energy usage. They wirelessly transmit data and can be controlled to turn power on or off. This strategy is effective for automatically controlling devices based on the device schedule and understanding full building and device specific energy usage and behavior.

Figure 4. Plug-in smart outlet. *Photo from WattIQ*

Advanced Power Strips

Advanced power strips (APS) are separate power strips that can be controlled manually or with sensors to shut off power to specific appliances. There are many APS providers and varieties that come with different capabilities to meet different needs. For example, depending on the APS purchased, there may be wireless transmission and energy monitoring capability (Earle and Sparn 2012). This strategy is most effective for controlling specific devices, rather than the whole building, and allows the linking of multiple appliances under the same control. To determine what control (schedule, load-based, occupancy) is most relevant for each device, see Table 2-2 in Lobato et al. (2012).

Automatic Receptacle Controls

Automatic receptacle controls are outlets installed in the building that can be controlled to shut off power to appliances based on schedule or occupancy. This may be done wirelessly, using sensors, or using buttons on the device. This strategy is effective for automatically controlling devices and for meeting the most recent ASHRAE standards (ASHRAE 2019) on PPL controls. To determine what method of control (schedule, occupancy) is most relevant for each device, see Table 2-2 in Lobato et al. (2012).

Figure 5. Automatic controlled receptacle. *Photo from Legrand*

Integrated Controls

Integrated controls are an emerging area that offers potential for connecting lighting, HVAC, and PPL systems to monitor and control them together. They are not widely available yet but will soon be relevant in the market. This strategy is effective for automatically controlling devices and understanding full-building and device-specific energy usage and behavior. Using various sensors (such as occupancy and photosensors), they can connect multiple systems for centralized control and monitoring and further interoperability. The sensor data is logged and can be analyzed to better understand energy savings and the building operation.

Figure 6. Advanced power strip and its installation. *Photos by Werner Slocum, NREL 46058, 46055*

Control Strategies	Wireless Meter and Control Systems	Advanced Power Strips	Automatic Receptacle Controls	Integrated Controls
Description	System of smart outlets that measure energy usage and turn devices on/off	Power strips that can be controlled to shut off power to specific appliances	Outlets that are installed in the building and can be controlled to turn devices on/off	Connects lighting, HVAC, and PPL systems to monitor and control them together
PPL Reduction Goal	Control PPLs using a device schedule and understand the PPL energy usage of the entire building	Control the energy usage of specific devices	Control PPLs using a device schedule or occupancy sensors and meet code requirements	Control PPLs alongside lighting controls and understand the PPL energy usage of the entire building.
Characteristics	• Wireless control • Automated system • Full picture of energy use • Device health monitoring	• Shared control of multiple devices • Focus on specific devices	• Wireless control • Automated system • Required for ASHRAE standard 90.1-2019 (ASHRAE 2019) compliance	• Wireless control • Automated system • Full picture of energy use • Device health monitoring • Connecting multiple systems • Interoperability
Metering	Use smart outlets	Use separate plug-in metering devices	Use separate plug-in metering devices	Use building management system
Load Analysis to Determine Device Attributes	Determine loads that: • Are high energy, especially in low-power modes (e.g., audio-visual systems) • Can be turned off or set to low power modes • Are used according to a building/device schedule	Determine: • Devices that could be connected • What controls (schedule, load-based, occupancy) are relevant	Determine loads that: • Are high energy, especially in low-power modes (e.g., audio-visual systems) • Can be turned off or set to low power modes • Are used according to a building/device schedule or according to occupancy	Determine loads that: • Are high energy, especially in low-power modes (e.g., audio-visual systems) • Can be turned off or set to low power modes • Can be connected to lighting/HVAC controls and sensors
Applying Controls	Program the smart outlets according to schedule	See NREL Guidance: How to Use Advanced Power Strips (NREL n.d.-c)	Program the controlled receptacles to be schedule-based or occupancy-based	PPLs are controlled by the building management system and lighting controls
Strategy Maintenance	• Reprogram plug-load management system to accommodate changes • Education and training • Check up on the plug load management dashboard /energy usage and provide feedback	• Check up on APS usage by occupants • Education and training	• Reprogram controlled receptacles system to accommodate changes • Education and training	• Education and training • Check up on the building management system dashboard/ energy usage and provide feedback

New Construction and Major Retrofits

New construction and retrofit projects bring additional PPL reduction opportunities that the design team should address. The champion should work with the design team to question standard specifications, operations, and design standards that limit energy savings opportunities. One major design change is to incorporate PPL controls and monitoring into the building infrastructure. The most recent ASHRAE codes (ASHRAE 2019) require that a percentage of outlets be controlled by automatic control devices. Automatic receptacle controls fulfill this requirement and are most easily incorporated in the design and construction phase when outlets are being installed. Installing separate submeters for PPLs is also beneficial to understand energy usage and realize many of the nonenergy benefits. It is also important to accurately assess required PPL capacity (W/ft2). Overestimating the PPL capacity, which is frequently done, results in over-sizing electrical infrastructure that increases capital costs and energy usage. In addition, the design team should consider process loads such as elevators, computing facilities, and cooking facilities to ensure that they are designed for maximum efficiency. This could involve finding the most energy-efficient models or incorporating waste heat recovery. With the increasing percentage of PPL energy use, these are crucial considerations during design and construction.

Appliance Specific Strategies

Point-of-Sale Equipment

Retail buildings generally have a large quantity of point-of-sale (POS) equipment. Typical cash register stations (cash register terminal, demagnetizer, bar code scanner/scale, handheld barcode scanner, and, occasionally, a conveyer belt) can have an energy cost of $100/year/POS if powered continuously. The power draw, combined with the extended use pattern, makes POS equipment a good candidate for energy reduction strategies.

Figure 7. Retail Point-of-Sale equipment. *Photo by Patrick Corkery, NREL 1578*

Refrigerators

In some retail buildings, vendor-supplied endcap refrigerators can be a significant source of PPLs; one solution is to require vendors to use only the most energy-efficient units and limit the number of endcap refrigerators on the sales floor.

For owner-supplied refrigerators located throughout the building:

☐ Remove underused refrigerators to save $40–$80/year/refrigerator.

☐ Replace aging, inefficient refrigerators with the most efficient refrigerators to save $40/year/refrigerator.

☐ Consolidate multiple mini-refrigerators into a full-size refrigerator to save $35/year/mini-refrigerator.

☐ Replace glass-door refrigerators with similarly sized solid-door refrigerators to save $60/year/glass-door refrigerator.

Self-Service Kiosks

Retail stores typically house a wide variety of self-service kiosks:

☐ Coin cashing/exchange machines

☐ Self-service photo printing machines

☐ DVD rental machines

☐ Purified water dispensing machines

☐ Lottery/scratch ticket machines

☐ ATMs

☐ Coffee grinders

☐ Gift registry kiosks

☐ Hiring center kiosks

☐ Price check kiosks.

Self-service kiosk energy consumption can be reduced in these ways:

☐ Turn off kiosks during nonbusiness hours (or during low occupancy times in 24-hour stores) to save as much as $90/year/kiosk.

☐ Set contractual requirements for vendors to use kiosks with built–in standby mode, and that "wake up" and are ready to use within seconds.

Electronics Section

Many stores sell a wide variety of electronics, and retailers often run these devices continuously to entice customers.

☐ Turn off televisions and other electronic displays during nonbusiness hours (or during low occupancy hours in 24-hour stores) to save as much as $40/year/television.

☐ Use nonfunctioning replica display models for small electronic devices, such as radios, alarm clocks, and cell phones to save $2/year/device.

☐ Turn off video game display aisles during nonbusiness hours (or during low occupancy hours in 24-hour stores) to save $375/year/video game aisle.

Office Equipment

Retailers typically have offices, break rooms, stockrooms, training rooms, and receiving docks in noncustomer areas that use typical office equipment.

Computers

☐ Replace standard desktop computers with miniature desktop, laptop, or thin client computers to save as much as $60/year/ computer.

☐ Disable screensavers and enable computer power management settings to save as much as $50/year/ computer with use of the computer management features (ENERGY STAR n.d).

☐ Configure computers so users can manually trigger standby or sleep mode via:

> ☐ The computer power button
>
> ☐ The laptop docking station power button
>
> ☐ Designated keyboard buttons
>
> ☐ A standby icon on the computer desktop
>
> ☐ Other external standby triggering devices.

Monitors

☐ Replace aging monitors with light-emitting diode (LED) backlit liquid crystal display (LCD) monitors to save $25/year/monitor (Lobato et al. 2011).

Task Lights

☐ Replace incandescent or fluorescent-tube task lighting with efficient compact fluorescent lamps or LED task lighting to save $30/year/task light.

Phones

☐ Replace standard phones with low-power (2 W maximum) voice over internet protocol phones to save $10/year/phone.

Printers, Copiers, Scanners, and Fax Machines

☐ Consolidate multiple personal devices into a single multifunction device to save $15/year/personal device.

☐ Enable the power option settings on the multifunction devices to go into standby after 15 minutes of idle time.

Security Monitors

Some retailers display the video from security cameras on sales floor cathode ray tube (CRT) security monitors to deter theft.

☐ Replace CRT security monitors with similarly sized LED backlit LCD displays to save as much as $90/year/display.

☐ Turn off security monitors during nonbusiness hours (or during low occupancy hours in 24-hour stores) to save as much as $40/year/display.

Drinking Fountains

☐ Limit drinking fountain coolers and bottled water coolers.

☐ Replace aging drinking fountains and bottled water coolers with noncooled drinking fountains to save $55/year/cooler.

Using the Workbook

Shown below is a sample of the workbook available for download in full as an Excel file. It will help you identify potential energy savings by reducing plug loads.

For each strategy listed, answer the question "Is your building doing this?" If your response is "No" for any strategy, fill out the adjacent cells to the right to determine the total approximate savings that the given strategy could yield in your building. Strategies that are listed without savings numbers are highly variable depending on the office building being assessed.

Strategies	Is your building doing this?			If you answered "NO," enter the quantity for each piece of equipment below to determine the approximate savings in your building.		
	YES	NO	N/A	Potential Energy Savings per Piece of Equipment	Quantity in Your Building	Potential Annual Savings for Your Building (kWh)
▶ **Point-of-Sale Equipment**						
Implement cash registers that feature an enabled standby mode	☐	☐	☐	**320 kWh/year** for every register that is powered down daily	x ____ =	
Set POS peripherals to turn off when not in use	☐	☐	☐	**80 kWh/year** for a register's peripherals that are powered down daily	x ____ =	
▶ **Vending Machines**						
Remove underused vending machines	☐	☐	☐	**3,500 kWh/year** for every refrigerated vending machine that is removed	x ____ =	

NOTE: Potential energy savings are based on an assumption of 14 hours of operation per work day

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