NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Building Owners | Energy Managers

OFFICE BUILDINGS | Assessing and Reducing Plug and Process Loads in Office Buildings

Overview

Plug and process loads (PPLs) account for 33% of U.S. commercial building electricity consumption (McKenney et al. 2010). (See Figure 1.) Minimizing these loads is a significant challenge in the design and operation of an energy-efficient building. Lobato et al. (2011) and Lobato et al. (2012) define PPLs as energy loads that are not related to general lighting, heating, ventilation, cooling, and water heating, and that typically do not provide comfort to the occupants. The percentage of total building energy use from PPLs is increasing. According to the U.S. Department of Energy (DOE), by 2030, commercial building energy consumption is expected to increase by 24%; PPL energy consumption is anticipated to increase by 49% in the same time frame (DOE 2010). These trends illustrate the importance of PPL energy reduction to achieve an overall goal of reducing whole-building energy consumption.

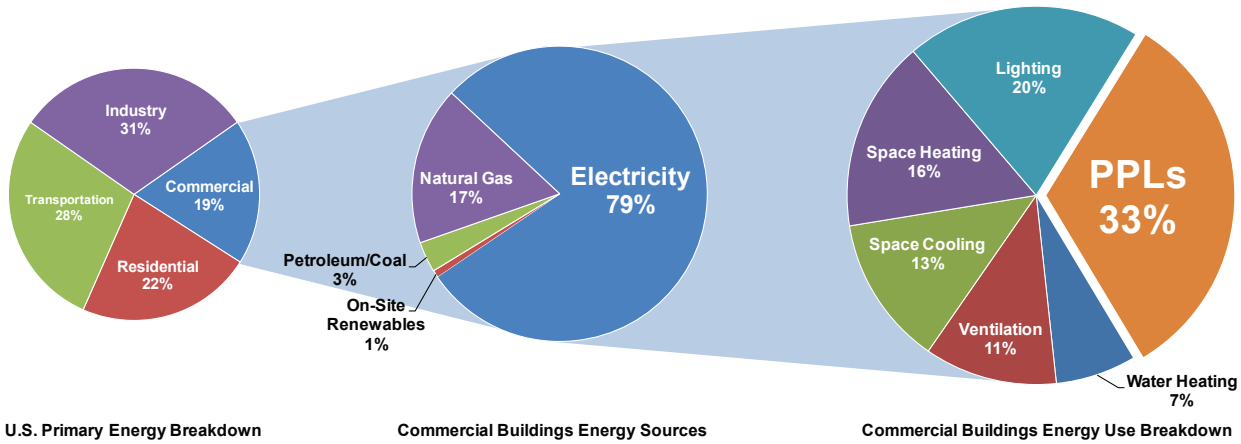

Figure 1. PPLs account for 33% of the total energy consumed by commercial buildings. *Graph by Chad Lobato, NREL; Data source: DOE (2010)*

Using the process and strategies outlined in this brochure, the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) was able to drastically reduce its PPL energy use in the Research Support Facility (RSF). NREL's previous office space PPLs used nearly 2,257,000 kWh/year; after implementing these PPL strategies, the RSF used 1,290,000 kWh/year (see Figure 2). At NREL's utility rate of $0.06/kWh, there is an annual cost saving of $58,000.

This "quick start guide" will help building owners and energy managers reduce PPL energy use in their facilities. This brochure provides an overview of PPLs in office buildings and describes the process and strategies needed to cost-effectively reduce their energy impact. 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.

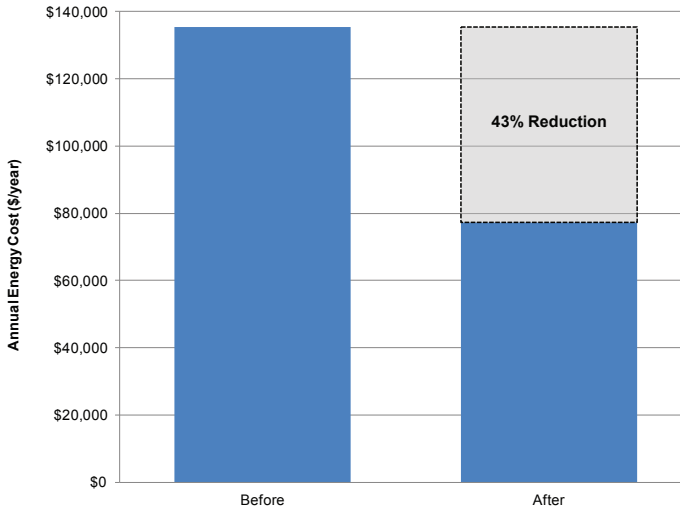

Figure 2. A 43% reduction in PPL energy use saves $58,000 annually. *Graph by Chad Lobato, NREL*

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Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Plug and Process Loads Reduction Process ▼

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 needs to understand basic energy efficiency opportunities and design strategies and be able to independently and objectively apply cost justifications. He or she must be willing and able to critically evaluate, address, and influence the building's operations, institutional policies, and procurement processes.

Historically, PPLs have not been targeted as an energy consumer such as lights or HVAC, and are considered a function of the building—in some ways, something you cannot do anything about. There are huge opportunities in understanding and managing these loads. Not only do they save energy directly, but cooling energy is also saved by not removing the heat generated by PPLs. PPLs are often specified by many parties, so equipment and efficiency strategies are rarely handled by one decision maker. The champion will make sure that all decision makers are on the same page about PPLs and that their decisions save energy and integrate well with other building systems.

Step 2: Institutionalize Plug and Process Load Measures

The day-to-day energy efficiency of any building depends largely on the decisions of occupants, 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 through procurement decisions and policy programs (refer to **ENERGY STAR®** for guidance). To do this, the champion must identify decision makers who can institutionalize programs based on identified PPL efficiency measures. Policies must be improved as needed to stay current with technologies.

Step 3: Benchmark Current Equipment and Operations

For a building that is representative of multiple buildings in a portfolio, the benchmarking process is required for only one building. The applicable strategies can then be implemented across the portfolio.

Step 3a: Perform a Walkthrough

A building walkthrough to identify and inventory PPLs will establish a benchmark of current equipment and operations. You can **download a workbook** to help in the inventory process and to estimate PPL energy use and costs. In this workbook, use the sheet named "Office PPL Inventory" to inventory the PPLs in your building. Use the sheet named "Office PPL Calculator" to determine which PPL strategies will offer the greatest savings in your building.

The champion will assess all PPLs, noting the various types of equipment and the quantity of each type. The champion needs to identify PPLs that are common throughout the building, and those that are present in limited quantities. At this stage, the champion will also engage the PPL users to learn how and why each device is used, and if the device is critical to health, safety, or business operations.

Frank et al. (2010) provided a detailed example of how a PPL walkthrough is conducted.

Step 3b: Develop a Metering Plan

A metering plan identifies energy-saving strategies by quantifying the energy use of PPLs. Such a plan saves time and money because only a representative sample of common items needs to be metered. For example, if every cubical has the same type of monitor, only a small sample needs to be metered. The PPLs that are present in limited quantities, that have unknown use patterns, or that are otherwise unique should all be metered if possible. The metering can be carried out, in part, with many commercially available PPL power meters. If metering is possible, the collected data can be used to understand when equipment is operated and highlight opportunities to turn off the equipment when it is not needed. If metering is not possible, either because the PPLs are hard-wired to the electrical system or because their voltage and current requirements are too great, you can **download a workbook** or refer to ASHRAE (2009), to estimate in-use power draws. You can then multiply an estimate by the hours of use to derive an estimate of actual energy use.

Another part of the metering plan is to identify PPLs that cannot be de-energized. Some PPLs cannot be de-energized because of:

- Health and safety concerns
- Interruptions to business operations
- Reductions in sales
- Shutdown procedures
- Reconfiguration requirements on startup.

If the PPL cannot be de-energized, use **the workbook** or ASHRAE (2009) to estimate the device's in-use power draw.

Step 3c: Select a Plug Load Power Meter

Many meters are commercially available to measure plug loads. A meter should have the following features:

- Ability to measure and log one week of electrical power (Watts) data. This offers a more accurate picture of energy use compared to a meter that provides only instantaneous readings.
- Sampling interval of 30 seconds
- Designed for the type of circuit to be metered (e.g., 120 Volt, 15 amp, 60 Hertz)
- Ability to accurately meter loads of 0–1800 W
- External display
- Internal clock that timestamps each data point
- Underwriters Laboratories listing
- Ability to download stored data.

Step 3d: Meter the Plug Loads

The steps to execute the metering plan for a given plug load are:

1. Assure the users that the purpose of the metering effort is to gather data about the building's energy performance, and not to monitor their personal or business activities.
2. If a business function will be interrupted by installing the meter, consider waiting until nonbusiness hours to do so.
3. If applicable, install any necessary computer software so the meter can be configured and the measured data can later be downloaded and analyzed.
4. Set up the meter to measure electrical power at a sampling interval of 30 seconds, if possible. Intervals as long as 15 minutes are acceptable. If necessary, clear the memory on the meter and go through any other initial setup, such as setting the date and time.
5. Power down and unplug the device to be metered, plug the device into the meter, plug the meter into an outlet, and power on the device.
6. Meter the device all day, every day for at least one entire work week. Time and budget permitting, meter for longer periods for more accurate annual energy use estimates and to capture seasonal use patterns.
7. Download the metered data for analysis. Calculate the average load during business and nonbusiness hours.

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

To gain buy-in from all parties involved, the champion must develop a business case that justifies measures to reduce PPLs.

In most projects, the initial business case is based on energy cost savings. Energy savings alone may not be sufficient to justify the most efficient PPL reduction strategy, so nonenergy benefits should be highlighted. For example, it is often difficult to justify purchasing low-energy laptop computers with energy cost savings alone. Laptops can be justified, however, because they enable users to work from home and to take their computers on travel. If mobility is not necessary, mini-desktops are available that have the efficiency of laptops without their added costs and security concerns.

Another example is centralized multifunction devices (compared to individual printers, copiers, and fax machines), which have reduced costs for maintenance and supporting unique toner cartridges. Minimizing, centralizing, and standardizing document services greatly simplify the implementation of robust standby power configurations and significantly lower service costs. Moreover, volatile organic compounds from the printer toners can be isolated to a few copy rooms with dedicated exhaust to improve indoor air quality. Depending on the building layout and function, as many as 300 printers can be replaced with as few as 20 widely distributed multifunction devices.

Step 5: Identify Occupants' True Needs

Identify occupants' and institutional true equipment needs. A true need is required to achieve a given business function; a perceived need is often based on past experience without consideration for more efficient strategies to accomplish the same function.

To reduce PPLs, the champion must understand what the occupants produce as part of their jobs and what tools they require. He or she must be diplomatic enough to help them do their jobs energy efficiently without making them feel that the purposes of their jobs are being questioned. This can be challenging, because every occupant, including those working in sensitive operations (e.g., security, information technology, upper management), should be accounted for. Determining occupant needs will reveal any nonessential equipment. A business case should be made for continued use of this equipment; otherwise, it should be removed. Exceptions can be made, especially for equipment that preserves occupant health and safety.

Certain PPLs may not be true needs, but are highly desirable. For these, the champion will need to work to meet the need with a shared, centralized piece of equipment and reduce or eliminate personal devices. For example, a shared, centralized coffee maker can meet employee demand and eliminate numerous personal coffee makers.

Step 6: Meet Needs Efficiently

Once the list of true needs is determined, each must be met as efficiently as possible. You should research the **ENERGY STAR** and **EPEAT**® databases to find energy-efficient equipment; however, these alone will not maximize cost-effective energy savings. Nonrated equipment should be researched to find the most efficient model. This will require the champion to work with equipment manufacturers and suppliers to determine the available options. Once a model is selected, it should be turned off when not in use, if possible.

A significant fraction of many PPLs' energy use is from parasitic loads, which is the power draw when a device is not performing useful work. Parasitic loads result in wasted energy, even if the equipment is energy efficient.

Step 7: Turn It All Off

Office buildings are unoccupied for two-thirds of the year. A key step in any PPL reduction program is to reduce energy use during nonbusiness hours, as it is generally wasted. Figure 3 shows a comparison between measured daily energy consumption for an ENERGY STAR-rated ice machine before and after timer control was implemented. Nearly $150/year was saved by installing a $20 electrical outlet timer—and the users still had all the ice they needed.

For detailed information about how to control PPLs, refer to Lobato et al. (2012).

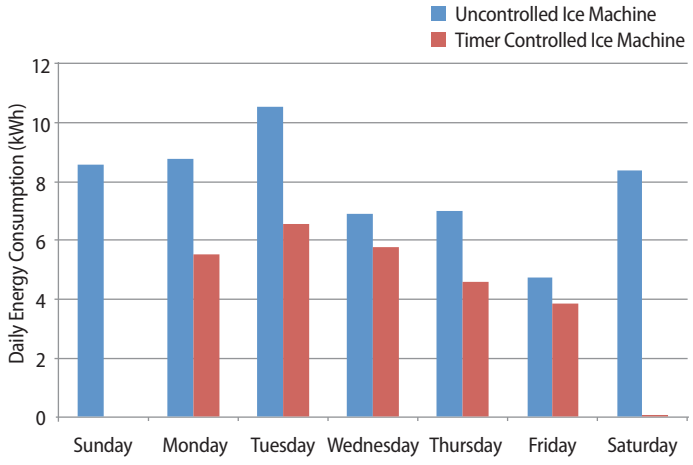

Figure 3. Ice machine daily load profile. *Graph by Chad Lobato, NREL*

Step 8: Address Unique Plug and Process Loads

Some equipment is not specified by building owners or employees. For example, outside contractors or vendors typically control food service areas, but the building owner covers their energy costs. For such situations, the owner should contractually require or provide the most efficient equipment available. Refer to ENERGY STAR and EPEAT for efficient options.

Energy-efficient gym equipment and ATMs may not be available and may be restricted from being turned off. These particular PPLs should be addressed on a case-by-case basis with the manufacturers to identify any possible solutions.

Step 9: Promote Occupant Awareness

A crucial step in reducing PPL energy use is to promote employee awareness of efficiency measures and best practices. Figure 4 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. Employee awareness can come in such forms as:

- Training
- Informational letters
- Emails
- Signage
- Videos
- Periodic reminders or updates.

Step 10: Address Plug and Process Loads (Design Team)

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 key role the design team plays in reducing PPLs is maximizing space efficiency, which increases the ratio of occupants per building area or piece of equipment. Increasing space efficiency decreases areas of dense PPLs, such as break rooms, common print areas, and cafeterias. Equipment in these areas is more efficiently used, and PPLs are reduced.

The design team has the opportunity to further reduce energy use by integrating PPL control strategies into the building's electrical system. Early in the design phase, the design team can build features into the electrical system to control the outlets at workstations and in common areas. This strategy can be as simple as installing switches, vacancy sensors, or timed disconnects for outlets, or as sophisticated as controlling outlets through the building management system.

The design team is typically responsible for specifying equipment such as elevators and transformers. The stairs should be designed to be as inviting and convenient as possible so employees want to use them. Elevators should then be carefully scrutinized to find the most efficient model. Some important features are reduced speed, occupancy-controlled lighting and ventilation, and smart scheduling.

The design team is also responsible for process cooling systems in areas with concentrated plug loads, such as information technology closets. These systems should use, where applicable, economizers, evaporative cooling, and waste heat recovery.

Figure 4. Sticker used at NREL to promote occupant awareness. *Illustration by Marjorie Schott, NREL*

Strategies ▼

The following best practices should be implemented to cost-effectively reduce PPL energy use without sacrificing functionality. When the following strategies recommend equipment replacement, refer to ENERGY STAR and EPEAT for energy-efficient options.

Note: The savings shown in the following strategies assume a utility rate of $0.10/kWh and an operating schedule of 10 business hours/day.

Break Rooms and Kitchens

Refrigerators

For refrigerators in break rooms and kitchens, implement the following:

- ☐ Remove underused refrigerators to save $40–$80/year/refrigerator.
- ☐ Replace aging, inefficient refrigerators with the most efficient compliant 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.

Small Kitchen Appliances

- ☐ Upgrade items such as coffee pots, toasters, and microwaves with units that have limited parasitic loads from light-emitting diode (LED) lights or displays to save $1/year/item.
- ☐ Control these items with electrical outlet timers so they are powered down during nonbusiness hours to save $3/year/item.

Vending Machines

Vending machines have an approximate energy cost of $350/year/refrigerated machine. Implement the following strategies to reduce vending machine energy consumption:

- ☐ Remove underused machines to save $350/year/machine.
- ☐ Replace aging, inefficient vending machines with the most efficient equipment to save $150/year/machine.
- ☐ Remove the display lighting to save $65/year/machine.
- ☐ Implement a load-managing device (**Deru et al. 2003**) to save $95/year/machine.
- ☐ Set contractual requirements for vendors to use only delamped, energy-efficient vending machines that have a load-managing device preinstalled.

Drinking Fountains

- ☐ Disconnect or remove drinking fountain coolers and bottled water coolers.
- ☐ Replace aging drinking fountains and bottled water coolers with noncooled drinking fountains to save $55/year/cooler.

Workstations

Workstations represent a significant fraction of office building PPLs and overall building energy use. Figure 5 is an example of a low-energy workstation.

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 2011**).
- ☐ 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 LED backlit liquid crystal display (LCD) monitors to save as much as $13/year/monitor (**Lobato et al. 2011**).

Task Lights

- ☐ Replace incandescent or fluorescent-tube task lighting with efficient compact fluorescent lamps (CFLs) or LED task lighting to save $15/year/task light.

Phones

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

Figure 5. Diagram of an example low-energy workstation.
Illustration by Matthew Luckwitz, NREL

Printers, Copiers, Scanners, and Fax Machines

- ☐ Consolidate multiple personal devices into a single multifunction device to save $8/year/personal device.
- ☐ Enable the power option settings on the multifunction devices to go into standby after 15 minutes of idle time.

Parasitic Loads

- ☐ Implement power management surge protectors at work stations to reduce or eliminate the parasitic loads of equipment during nonbusiness hours.
- ☐ For detailed information about how to control PPLs, refer to **Lobato et al. (2012)**.

Vertical Transport

Elevators

Elevator car lighting and ventilation are typically powered whether or not the car is occupied.

- ☐ Control elevator lighting and ventilation with occupancy sensors to save as much as $100/year/elevator.

Stairs

Building occupants should be encouraged to use stairs to reduce energy use and improve health.

Escalators

Escalators generally operate continuously during business hours, and in some cases continuously during nonbusiness hours.

- ☐ Control escalators so that they operate only during business hours or when needed to save as much as $900/year/escalator.

Small-Scale Food Service Areas

As with the break rooms and kitchens, replacing aging, inefficient equipment with the most efficient **ENERGY STAR** equipment will save energy. Food service areas present unique challenges because they are often outfitted and operated by outside vendors. It is important to work with the vendor to supply energy-efficient PPLs that meet their needs.

Refrigerators

- ☐ Remove underused refrigerators to save$40–$80/year/refrigerator.
- ☐ Replace aging, inefficient refrigerators with the most efficient compliant refrigerators to save $40/year/refrigerator.
- ☐ Consolidate multiple mini-refrigerators into a full-size refrigerator for a savings of $35/year/mini-refrigerator
- ☐ Replace glass-door refrigerators with similarly sized solid-door refrigerators to save $60/year/glass-door refrigerator.
- ☐ Set contractual requirements for vendors to use only the most efficient commercial refrigerators.

Nonrated Equipment

For equipment that is not rated by ENERGY STAR, or similar organizations, those responsible for specification and procurement should work directly with manufacturers to determine the most efficient option. Many manufacturers offer low-energy equipment options.

Small Kitchen Appliances

- ☐ Upgrade items such as coffee pots, toasters, and microwaves with units that have limited parasitic loads from status LED lights or displays to save $1/year/item.
- ☐ Control these items with electrical outlet timers so they are powered down during nonbusiness hours to save $3/year/item.
- ☐ Set contractual requirements for vendors to use only the most energy-efficient items.

Parasitic Loads

Food service equipment can have large parasitic loads during nonbusiness hours.

- ☐ Control equipment with electrical switches, or a similar method, to easily disconnect power to all nonessential equipment during nonbusiness hours.
- ☐ Set contractual requirements for vendors that will ensure that the equipment is disconnected and powered down during nonbusiness hours.

Conference Room Equipment

Conference rooms are subject to varying use schedules.

- ☐ Implement controls that disconnect or turn off equipment when the space is unoccupied. Electrical outlet timers can be used to power down equipment during nonbusiness hours. Occupancy sensors can be used to disconnect power when the rooms are unoccupied during business hours.
- ☐ Outfit the space with energy-efficient equipment. LED backlit LCD televisions and energy-efficient projectors should be used for display purposes.

Server Room Equipment

- ☐ Implement an uninterruptible power supply that has the following features:
  - ☐ At least 95% energy efficiency
  - ☐ Scalable design
  - ☐ Built-in redundancy
  - ☐ End user serviceable
  - ☐ Sufficient uptime until the backup generator starts
  - ☐ Meets the efficiency guidelines of the **Server System Infrastructure** initiative, which sets open industry specifications for server power supplies and electronic bays.
- ☐ Load the uninterruptible power supply so it operates at peak efficiency.
- ☐ Use energy-efficient power distribution units.
- ☐ Use blade servers with variable-speed fans and energy-efficient power supplies.
- ☐ Implement virtualization software.
- ☐ Implement a hot aisle/cold aisle configuration.
- ☐ Implement hot aisle containment .
- ☐ Depending on climate zone, implement economizers and evaporative cooling.
- ☐ Capture waste heat from the servers for use in other areas of the building.

NREL (2013) and **Sheppy et al. (2011)** provide more details about energy reduction strategies in server rooms and data centers.

Telecommunications Room Equipment

Typical telecommunications rooms provide continuous power to all Ethernet switches and ports.

- ☐ Power these switches and ports based on occupant needs.

Additional Strategies

For office buildings that have large file storage needs, motorized compact shelving units should be replaced with manual hand crank compact shelving units to save energy.

Management policies should be implemented to address PPLs. These policies should minimize or eliminate the use of personal electronic equipment (coffee makers, fans, heaters, mini-refrigerators, decorative lighting, etc.) at the workstations. The policies should establish a standardized list of the energy-efficient equipment to be used in the building. They should provide a process for addressing atypical circumstances that may warrant what would otherwise be excessive PPL energy use.

For items that have not yet been addressed, refer to Lobato et al. (2011b) for the process required to power down PPLs when not in use. Items such as lobby displays, ice machines, and exercise equipment can be effectively controlled by commercially available control devices. The devices should be configured so the equipment is powered only during business hours.

For new construction and extensive retrofits, it is good practice to aggregate plug loads onto dedicated electrical panels. With dedicated plug load panels, the circuits can be integrated with the building control system to turn off all plug loads during nonbusiness hours. These panels also allow for easy energy submetering, which can be used to develop a building PPL energy use display system that can provide feedback to the building occupants.

Recommended Plug Load Energy Reduction Strategies for Office Buildings

Shown on the following page 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.		
Strategies	**YES**	**NO**	**N/A**	**Potential Energy Savings per Piece of Equipment**	**Quantity in Your Building**	**Potential Annual Savings for Your Building (kWh)**
▶ Break Rooms and Kitchens						
Remove underused refrigerators	☐	☐	☐	**400 kWh/year** for every underused refrigerator that is removed	x___=	
Replace aging, inefficient refrigerators with one of the most efficient, full-size ENERGY STAR® refrigerators for every 60 people	☐	☐	☐	**400 kWh/year** for every inefficient refrigerator that is replaced	x___=	
Consolidate personal mini-refrigerators into a full-size shared refrigerator	☐	☐	☐	**350 kWh/year** for every mini-refrigerator that is removed	x___=	
Replace glass-door refrigerators with similarly sized solid-door refrigerators	☐	☐	☐	**600 kWh/year** for every glass-door refrigerator that is replaced	x___=	

NOTE: Potential energy savings are based on an assumption of 10 hours of operation per work day

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