Reducing Plug and Process Loads for a Large Scale, Low Energy Office Building: NREL's Research Support Facility

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ABSTRACT

The construction of the National Renewable Energy Laboratory's (NREL) new 220,000-ft^2 (20,438-m^2) Research Support Facility (RSF) was completed in June 2010. The project's Request for Proposals (RFP) set a whole-building demand-side energy use requirement of a nominal 25 kBtu/ft^2·yr (78.8 kWh/m^2·yr). The RSF baseline plug and process loads (PPLs) were 35.1 kBtu/ft^2·yr (110.6 kWh/m^2·yr). To meet the building energy goal, PPLs had to be reduced by approximately 50%. This paper documents the methodology NREL researchers developed to identify and reduce PPLs as part of the RSF's low energy design process. They examined PPLs, including elevators, kitchen equipment in breakrooms, and office equipment in NREL's previously occupied office spaces to determine a baseline. This, along with research into the most energy-efficient products and practices, enabled these researchers to formulate a reduction strategy that should yield a 47% reduction in PPLs. The building owner and the design team played equally important roles in developing and implementing opportunities to reduce PPLs. Based on the work done in the RSF, a generalized multistep process has been developed for application to other buildings.

INTRODUCTION

The Research Support Facility (RSF) is projected to achieve annual net zero energy use with on-site renewables and be one of the largest U.S. net zero energy office buildings. The project's Request for Proposals (RFP) set a whole-building demand-side energy use requirement of a nominal 25 kBtu/ft^2·yr (78.8 kWh/m^2·yr) (Pless et al. 2010) that sparked an investigation into benchmarking current plug and process loads (PPLs).

Overall, PPLs in residential and commercial buildings account for almost 12% of U.S. primary energy consumption (McKenney et al. 2010). Minimizing these loads is one of the primary challenges in the design of an energy-efficient building. PPLs are not related to general lighting, heating, ventilation, cooling, and water heating, and typically do not provide comfort to the occupants. They use an increasingly large portion of the building energy use pie because the number

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and variety of electrical devices have increased along with the efficiency of building systems. Reducing PPLs is difficult because there is a limited understanding of energy efficiency opportunities and equipment needed to address office space PPL energy use. Typically, no single decision maker can specify all efficiency strategies for PPLs, which makes centralized educated decisions about possible strategies difficult. The owner, tenant, engineer, architect, information technologies (IT) procurement staff, and facility operator all can make decisions about efficient PPLs. Furthermore, most PPLs are not included in ASHRAE 90.1 and are typically not addressed by building codes. This paper outlines reduction strategies that were developed for the RSF. These can be used in any building, but are most effective at the beginning of the design stage.

DEVELOPMENT, IMPLEMENTATION, AND RESULTS OF PLUG AND PROCESS LOAD STRATEGIES

This section includes an overview of RSF PPL strategies. The results from a survey of NREL campus PPLs are presented with proposed energy saving strategies. Energy savings predictions are made based on the strategies and recommended equipment.

Plug and Process Load Survey

The RSF posed a unique challenge. The design team was contractually required to meet a whole-building energy use goal that included PPLs. To accurately account for PPLs, the team required input from NREL on previous and proposed equipment and use. A team of NREL researchers was assigned to be PPL champions, and began by performing a thorough survey of NREL's equipment use.

An equipment inventory was developed from the PPL survey. A representative sample was then metered to develop use profiles and determine peak and standby energy use. The metered data revealed a baseline PPL energy use of 35.1 kBtu/ft^2·yr (110.6 kWh/m^2·yr), which would have made it impossible to meet the energy goal. Therefore, RSF PPLs had to be reduced by approximately 50%. The strategies and resulting reductions are discussed in the following sections.

Implementation of Plug and Process Load Strategies

Data Center. NREL's previous data center used a number of servers that typically had a utilization of less than 5%. When the total data center power draw was divided among all users, the continuous power consumption rate per person was 65 W. The uninterruptible power supply (UPS) and room power distribution units were 80% efficient. The RSF data center uses blade servers running virtualized servers. When the total data center power draw is divided among all users at NREL, the continuous power consumption rate per person is 35 W. The current UPS and room power distribution are 97% efficient.

Copiers, Printers, and Fax Machines. The initial PPL audit revealed that many workstations had their own single-user machines (copiers, printers, fax machines, and scanners). All-in-one copying and printing stations had approximately 40 users on average, and many operated in an always-on mode.

In the RSF, each all-in-one printing station is used by approximately 60 occupants. Through better space planning and understanding of common space utilization, the design team was able to reduce the total number of shared all-in-one printing stations by a third. IT and management put in place policies that have eliminated shared and personal single-function machines wherever possible. Using fewer shared multifunction devices reduces capital and maintenance costs, as well as wasted energy when the machines sit idle. The standby features are activated and used to reduce night and weekend energy consumption from 175 W to 20 W continuous.

By using centralized print stations, people with significant printing needs face some limitations, as they previously had personal machines at their workstations. Some view the shared devices as an inconvenience because they can no longer retrieve printouts at their desks; further, some people objected because they did not want to send sensitive print jobs to a shared device. To keep such materials private, shared devices feature password protection. In addition, many of the NREL business processes are going toward electronic approvals limiting the need for printers substantially.

Computers and Monitors. The PPL audit revealed numerous opportunities to reduce PPLs from workstation equipment. Approximately 90% of employees used desktop computers. When idle, these computers went into a screensaver mode or displayed an idle desktop screen. Monitors were typically either fluorescent backlit LCD or CRT displays. To reduce computer energy consumption, 90% of the RSF occupants use laptop computers with LED backlit LCD monitors. Figure 1 shows the measured load profile of a laptop computer and two 22” (56 cm) LED backlit LCD monitors.

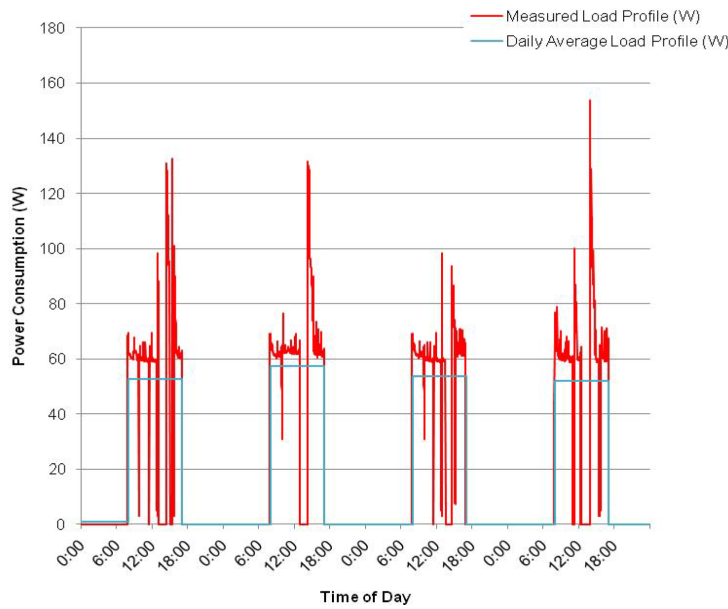


Figure 1 *Laptop computer and monitor load profile*

The average power draw for this laptop and display combination was 53.9 W during occupied hours and 4 to 5 W during unoccupied hours. Further savings during unoccupied hours are achieved with a controlled outlet on a power management surge protector to eliminate the parasitic load of the docking station and battery charging (see Figure 1).

One commonly expressed concern involved the perception that laptops cannot always provide the computing power required. This may be true when substantial computing is needed, but most employees perform only standard business functions. Desktops are issued to those few employees who are truly limited by laptop capabilities.

The previous strategy for dealing with idle computers was to lock them out after 15 minutes and to display a security screensaver. The screensaver *increased* average power by 5 W compared to an idle state (30 to 35 W for a laptop locked out in the security screensaver versus 25 to 30 W for a laptop in use). Setting the monitor into a standby state while the computer runs the screensaver reduces power draw, but is not an optimal solution. Setting both the computer and monitor into standby produces the most energy savings, reducing power to 4 to 5 W.

Task Lights, Phones, and Power Management. Additional equipment in the previously occupied workstations included a task light, a phone, and miscellaneous items such as cell phone chargers, lights (decorative or functional, or both), mini refrigerators, coffee pots, electric teapots, fans, personal heaters, label makers, and radios. The task lighting used traditional linear fluorescent lamps and fixtures and the phones were standard models. The items received power from standard six-plug surge protectors.

Workstation area lighting, especially task lighting, was a challenge for the RSF’s unique design. In conventional office buildings, occupants are accustomed to lighting levels that far exceed the minimum requirements. The RSF is designed to be 100% daylit, so supplemental lighting comes from efficient 6 W LED task lighting and overhead electrical lighting. RSF employees are provided with VOIP phones that consume a constant 2 W.

Power at the workstation is managed primarily through new power management surge protectors that have low or no parasitic loads, manage power, and are aesthetically pleasing and cost effective. Each has four controlled outlets and four always-powered outlets. When power draw on the sensor outlet drops below a manually set threshold, power is cut to the controlled outlets. They are desktop mounted so the main power button is easily accessible.

Typically, commercial building occupants are unaware of their energy use. In the RSF, occupant behavior and equipment are the driving forces behind energy use. All occupants need to be aware of how their energy use affects the RSF's overall performance. This awareness drives people to eliminate items that waste energy and are unnecessary.

Appliances. A key design team contribution to reducing PPLs included maximizing space efficiency in shared areas. The previously occupied NREL office buildings provided breakrooms with refrigerators, microwaves, coffee pots, drinking fountains, and vending machines. The RSF features the same amenities, but each breakroom serves approximately 60 building occupants compared to 40 in previously occupied NREL buildings. This increase will reduce the number of energy-consuming appliances. Further savings are accomplished in the breakrooms by purchasing efficient refrigerators (48 W average load) and eliminating mechanically cooled drinking fountains.

Every floor on each wing has two kitchens. They have ample refrigerator space, dishwashers, coffee makers, and microwaves to eliminate the need for personal equipment. Management and safety policies disallow the use of personal equipment at individual workstations. Special cases are considered for business or other justified reasons.

Elevators. The RSF employs energy-efficient regenerative traction elevators rather than the standard hydraulic elevators that typically operate in low-rise office buildings. Each elevator has a potential annual saving of 7000 kWh (KONE 2006), depending on use, compared to standard hydraulic elevators. Each is equipped with energy-efficient fluorescent lighting and fans, which are turned off when the car is unoccupied. The stairwell design is inviting (to encourage their use), with wide steps, windows with mountain views, and a variety of art pieces at each floor.

Miscellaneous Loads. The RSF offers the same amenities as do previous NREL office spaces, including a coffee kiosk, a gym, an ice machine, and vending machines. The previous coffee kiosk provided a variety of hot and cold beverages and food to occupants in three of NREL's buildings. The espresso machine and water heater were left powered 24/7. The espresso machine had a continuous average load of 455 W. Multiple glass-front mini refrigerators were used to store food and cold drinks. Overall, the previous coffee kiosk had an average continuous load of nearly 1400 W.

The RSF coffee kiosk is significantly more energy efficient. The espresso machine goes into standby mode when it is not in use during occupied hours, and is turned off during unoccupied hours. The manufacturer claims a 30% in-use energy savings (General Espresso Equipment Corporation 2009). It has an estimated continuous average load of 150 W. Food and cold drinks are stored in full-size refrigerators with nontransparent doors. All mini refrigerators have been eliminated. Timed outlets cut power to all items except the refrigerators, freezer, and cash register during unoccupied hours. Overall, the coffee kiosk has an estimated average continuous load of nearly 700 W. The ice machine is controlled by a timer to it turn off during unoccupied hours, which reduces continuous power draw from 327 W to 110 W. The RSF has two ENERGY STAR® soda machines and one snack machine that feature efficient LED display lighting (the lighting is deactivated to achieve additional energy savings) (Deru et al. 2003).

Results

The innovative application of energy-efficient PPL equipment and design strategies result in overall savings of 47% for PPLs and 51% for the whole RSF building compared to the previously occupied NREL office space. By integrating the PPL strategies along with the other efficient building systems, the RSF has an expected whole-building energy use of 35.1 kBtu/ft^2·yr (110.6 kWh/m^2·yr) [10.6 kBtu/ft^2·yr (33.4 kWh/m^2·yr) of which is for data center equipment]. Because of the goal of a Zero Energy Building (ZEB), additional loads must be offset with a photovoltaic (PV) system. These strategies resulted in a PV cost savings of more than $4 million. See Table 1 for a detailed description of each PPL energy-saving strategy, before and after EUIs, and photovoltaic (PV) cost savings.

The reduced PPLs account for 55% of the total energy use in the RSF. Figure 2 shows the RSF whole-building energy use breakdown. To achieve low energy consumption, and potentially net zero energy, the design team, owners, and operators must find opportunities to address PPLs.

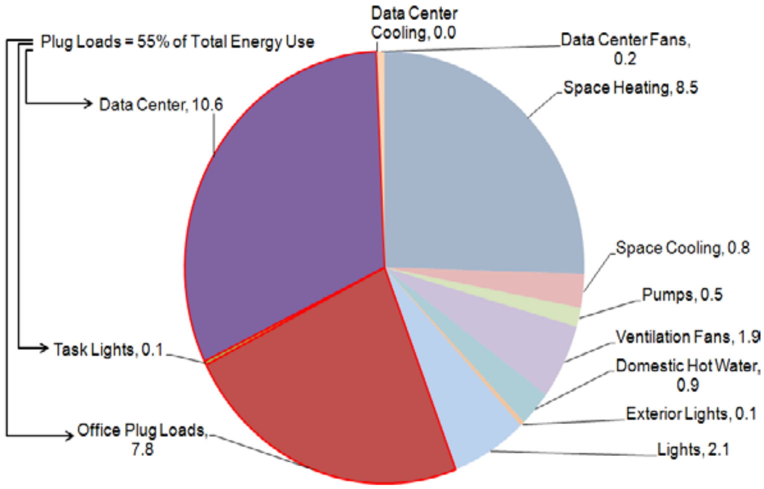
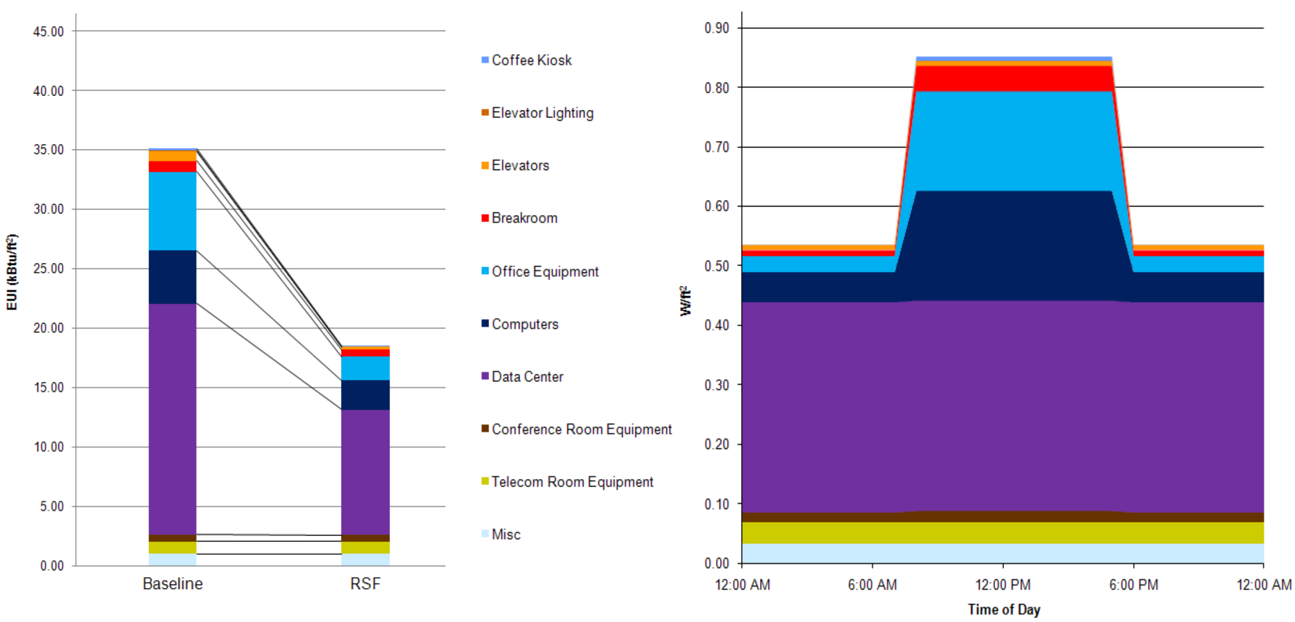


Figure 2 *RSF whole-building energy use breakdown (kBtu/ft²·yr)*

As shown in Figure 3a, the PPL energy use intensity (EUI) in the RSF was reduced from the baseline 35.1 kBtu/ft²·yr (110.6 kWh/m²·yr) to an estimated 18.5 kBtu/ft²·yr (58.3 kWh/m²·yr). The largest PPL energy savings in the RSF comes from the new strategies for the data center, computers, and office equipment. Figure 3b shows the RSF equipment power density to be about 0.85 W/ft² (9.1 W/m²) during the day and about 0.54 W/ft² (5.8 W/m²) at night, of which a continuous 0.35 W/ft² (3.8 W/m²) is data center load.



a) b)

Figure 3 *(a) Baseline vs. RSF plug and process load EUI (b) RSF Low-Energy plug and process load equipment power density schedule*

Table 1. Summary of Energy Efficiency Measures in the RSF and Their Expected Effects

Areas		Current Consumption kBtu/ft²·yr (kWh/m²·yr)	Strategies	RSF kBtu/ft²·yr (kWh/m²·yr)	Energy Savings kBtu/ft²·yr (kWh/m²·yr)	PV Cost Savings
Data Center	Servers	19.43 (61.22)	• 35W per occupant blade servers replaced 65W per occupant standard servers • Servers receive power from a 96% efficient UPS and a 98.6% efficient power distribution unit • Blade servers are virtualized to save energy • Up to 20 virtualized servers can be run on one physical server	10.56 (33.27)	8.87 (27.95)	$2,189,689
Work Station	Copiers	1.34 (4.22)	• Multifunction devices replaced single-function copiers, printers, and fax machines • Eliminate personal copiers and fax machines • Decrease the use of personal printers by 75% • Increase the number of users from 40 to 60 per multifunction device • Monitoring to ensure standby modes are operational and effective	0.74 (2.33)	0.60 (1.89)	$149,645
	Printers	2.92 (9.20)		0.90 (2.84)	2.02 (6.37)	$497,060
	Fax Machines	0.02 (0.06)		0.00 (0.00)	0.02 (0.06)	$5,513
	Computers and Monitors	4.49 (14.15)	• 30W laptop computers replaced 100W desktop computers • 15W - 18W 22" - 24" (56cm – 61cm) LED backlit LCD monitors replaced older 25W - 50W 19" - 24" (48cm - 61cm) fluorescent backlit LCD monitors and 70W CRT monitors (one, 18W 24" (61cm) monitor or two, 15W 22" (56cm) monitors are used per occupant) • Power management surge protectors eliminate parasitic losses when space is unoccupied • Monitoring to ensure standby modes are operational and effective	2.43 (7.66)	2.06 (6.49)	$506,335
	Task Lights	0.54 (1.70)	• 6W LED task lights replaced 35W fluorescent task lights • Power management surge protectors eliminate parasitic losses when space is unoccupied • Monitoring to ensure standby modes are operational and effective	0.10 (0.32)	0.44 (1.39)	$107,990
	Phones	1.79 (5.64)	• 2W VOIP phones replaced 15W standard phones	0.28 (0.88)	1.51 (4.76)	$375,038
Breakroom	Refrigerators	0.27 (0.85)	• The most efficient continuous 48W ENERGY STAR refrigerators were specified • Increase number of users from 40 to 60 per breakroom	0.18 (0.57)	0.09 (0.28)	$22,051
	Coffee Pots	0.22 (0.69)	• Increase number of users from 40 to 60 per breakroom • Eliminate equipment with parasitic loads, such as status LEDs • Monitoring to ensure standby modes are operational and effective	0.14 (0.44)	0.08 (0.25)	$17,699
	Microwaves	0.21 (0.66)		0.14 (0.44)	0.07 (0.22)	$17,398
	Vending Machines	0.17 (0.54)	• Most efficient ENERGY STAR vending machines were specified and delamped • Increase number of users from 100 to 400 per vending machine	0.12 (0.38)	0.05 (0.16)	$11,971
	Drinking Fountains	0.07 (0.22)	• Water coolers were eliminated from drinking fountains • Bottled water coolers were eliminated by providing filtered water at the tap	0.01 (0.03)	0.06 (0.19)	$14,294
Elevators	Elevators	0.80 (2.52)	• Regenerative traction elevators replaced hydraulic elevators	0.25 (0.79)	0.55 (1.73)	$137,015
	Elevator Lighting	0.08 (0.25)	• The elevator lighting and fans turn off when the elevator is unoccupied	0.00 (0.00)	0.08 (0.25)	$19,940
Telecom Room Equipment		1.05 (3.31)	• Power and enable individual Ethernet switches based on occupant needs	1.05 (3.31)	NA[1]	NA[1]
Conference Room Equipment		0.58 (1.83)	• 120W 55" (140cm) LED backlit LCD TVs replaced older 200W - 300W 55" (140cm) fluorescent backlit LCD TVs in conference rooms	0.55 (1.73)	0.03 (0.09)	$7,931

Areas		Current Consumption kBtu/ft²·yr (kWh/m²·yr)	Strategies	RSF kBtu/ft²·yr (kWh/m²·yr)	Energy Savings kBtu/ft²·yr (kWh/m²·yr)	PV Cost Savings
Coffee Kiosk	Espresso Machine	0.06 (0.19)	• An efficient espresso machine with built in standby mode replaced an older, uninsulated espresso machine that was powered 24/7 • Monitoring to ensure standby modes are operational and effective	0.02 (0.06)	0.04 (0.13)	$8,885
	Refrigerators	0.04 (0.13)	• The most efficient continuous 48W ENERGY STAR commercial refrigerators were specified • Refrigerators with solid fronts were specified instead of refrigerators with glass fronts • A full-size refrigerator replaced multiple mini refrigerators	0.01 (0.03)	0.03 (0.09)	$5,677
	All Equipment	0.08 (0.25)	• Eliminate equipment with parasitic loads, such as status LEDs • Provide switches to disconnect all non-essential equipment during non-business hours. Include contractual requirement for operator to disconnect all non-essential equipment. • The most efficient ENERGY STAR commercial chest freezer was specified • Monitoring to ensure standby modes are operational and effective	0.03 (0.09)	0.05 (0.16)	$10,119
Miscellaneous		0.97 (3.06)	• Motorized compact shelving was replaced by hand crank compact shelving • Motion sensors/time clock outlets are used to turn off miscellaneous loads when not in use (lobby energy monitors, ice machine, exercise equipment, etc.) • Implement management policies to minimize or eliminate use of personal electronic equipment (personal coffee makers, fans, heaters, mini refrigerators, decorative lighting, etc.) • Miscellaneous workstation equipment will be controlled by smart power strips, such as head set chargers, cell phone chargers, label makers, radios, etc. • IT recommended USB-powered peripherals rather than standard 120V devices (external hard drives) • Computer standby settings are used to lock out idle computers instead of using screen savers	0.97 (3.06)	NA[1]	NA[1]
TOTAL		**35.13 (110.69)**		**18.48 (58.23)**	**16.65 (52.46)**	**$4,104,251**

[1] In cases where no energy savings are shown, the savings are not quantified for the strategies implemented.

HIGH-LEVEL RECOMMENDATIONS FOR REDUCING PLUG AND PROCESS LOADS IN A LOW ENERGY BUILDING

Every building should address the issue of PPLs. This is especially critical for buildings striving for specific low-energy targets, such as a ZEB. Simply adding more renewable generation to offset wasteful devices, operations, and processes is not practical because of space and cost considerations. The strategies used to address PPLs in the RSF are documented and generalized in the next section. These strategies are primarily relevant to buildings that are in the design, construction, or commissioning phases. Even if net zero energy is not the goal for the building being considered, these strategies will help reduce PPLs in any type of building.

Strategies for Addressing Plug and Process Loads

Establish a PPL champion. The first step in designing PPLs in a low energy building is to establish a PPL champion (or a team of champions) to initiate and help with these strategies. This person needs to understand technical energy efficiency opportunities and design strategies. Also, the champion must be able to independently and objectively apply business model cost justifications to be able to question the owner's operations, institutional policies, and procurement processes.

Develop a business case for addressing PPLs. To gain buy-in from all parties involved, especially the building owner, the champion must develop a business case for addressing PPLs. For projects such as the RSF with net zero energy goals, one powerful strategy is the avoided cost of renewables (ACR) metric. The ACR equates the cost of PPL efficiency measures to avoided renewable costs. The ACR gives all parties a financial incentive to investigate PPLs and pay close attention to mass-distributed items and large load, low quantity, continuous use items.

To meet the RSF's net zero energy goals, an ACR was used to justify demand-side efficiency measures. For every one Watt continuous saved, $33 worth of PV was avoided. The PV cost avoided by PPL reductions exceeded $4 million.

At a whole-building EUI of 25 kBtu/ft^2·yr (78.8 kWh/m^2·yr), a building will achieve a diminishing return on investment into demand-side reductions. At this point, it becomes economically advantageous to invest in supply-side measures, such as PV, to reduce net energy consumption.

Benchmark your conventional equipment and operations. An energy audit needs to be performed to establish a baseline of PPLs and operations. It can be carried out, in part, with many commercially available PPL power meters. If PPLs cannot be studied with conventional meters, a combination of submetering and manufacturers' specification sheets can be used. Once the data from the energy audit are collected, they can be used to understand when equipment is used and highlight opportunities to turn off the equipment when it is not in use. The energy audit also serves as a basis of comparison for using the ACR metric.

Be willing to identify occupants' true needs. The next important step is to assess occupant and institutional true needs. A true need, as opposed to a perceived need, is required to achieve a given business goal or an assigned task. Oftentimes occupants perceive that they must use a certain piece of equipment in a particular way to do their jobs; however, their perceived method may not be the most energy-efficient. For example, some researchers in the RSF had the perception that they needed to leave their computers powered on during unoccupied hours so they could remotely run a simulation. The true need in this case is for researchers to have remote access to a simulation workstation at any time. To address this true need, and with energy efficiency in mind, certain workstations were configured to use Wake-on-LAN functionality. This enables researchers to leave their computers in standby mode and still access them remotely.

To reduce PPLs, the PPL champion must be willing to understand what the occupants produce as part of their jobs and what tools they require. This must be approached diplomatically so as not to question the occupants' purposes but to help them do their jobs in an energy-efficient way. This can be challenging, because every occupant, including those working in sensitive operations (e.g., security, IT, upper management), must be accounted for. Determining occupant needs will reveal any nonessential equipment. A business case must then 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.

Meet needs as efficiently as possible. Once the list of true occupant and institutional needs is determined, each must be met as efficiently as possible and combined with accurate use scheduling. Simply specifying ENERGY STAR and EPEAT equipment is not sufficient. These databases should be thoroughly reviewed and the most efficient equipment must be specified. Nonrated equipment must be researched to find the most efficient model, which should be turned off when not in use, if possible. Parasitic loads require special attention, even if the equipment is energy efficient. There will always a more efficient way to perform operations. This is accomplished by using more efficient equipment in a more efficient manner.

Turning it all off. Office buildings are unoccupied for two-thirds of the year. Historically, the average unoccupied PPLs are about half the occupied PPL density (Torcellini et al. 2006). A key strategy in any PPL reduction program is to reduce power density during nonbusiness hours. Table 2 shows the annual plug load EUI for a given average daytime and nighttime power density. (The table was developed assuming nine occupied hours per work day and 250 work days per year.) Minimizing nighttime PPLs significantly reduces the annual EUI. The area outlined in red shows the targeted PPL densities and EUIs for the RSF, excluding the data center. Daytime PPLs are about 0.50 W/ft^2 (5.38 W/m^2); nighttime PPLs are about 0.19 W/ft^2 (2.05 W/m^2).

Table 2. Annual Plug and Process Load EUIs (Excluding the Data Center) Based on Day and Night Power Densities

	Annual Plug Load Energy Use Intensity (kBtu/ft^2·yr)														
	Unoccupied Hours Power Density (W/ft^2)														
Occupied Hours Power Density (W/ft^2)	**0.10**	**0.20**	**0.30**	**0.40**	**0.50**	**0.60**	**0.70**	**0.80**	**0.90**	**1.00**	**1.10**	**1.20**	**1.30**	**1.40**	**1.50**
0.10	3.0	5.2	7.4	9.7	11.9	14.1	16.3	18.6	20.8	23.0	25.2	27.4	29.7	31.9	34.1
0.20	3.8	6.0	8.2	10.4	12.7	14.9	17.1	19.3	21.5	23.8	26.0	28.2	30.4	32.7	34.9
0.30	4.5	6.8	9.0	11.2	13.4	15.6	17.9	20.1	22.3	24.5	26.8	29.0	31.2	33.4	35.6
0.40	5.3	7.5	9.7	12.0	14.2	16.4	18.6	20.9	23.1	25.3	27.5	29.7	32.0	34.2	36.4
0.50	6.1	8.3	10.5	12.7	15.0	17.2	19.4	21.6	23.8	26.1	28.3	30.5	32.7	35.0	37.2
0.60	6.8	9.1	11.3	13.5	15.7	17.9	20.2	22.4	24.6	26.8	29.1	31.3	33.5	35.7	38.0
0.70	7.6	9.8	12.0	14.3	16.5	18.7	20.9	23.2	25.4	27.6	29.8	32.1	34.3	36.5	38.7
0.80	8.4	10.6	12.8	15.0	17.3	19.5	21.7	23.9	26.2	28.4	30.6	32.8	35.0	37.3	39.5
0.90	9.1	11.4	13.6	15.8	18.0	20.3	22.5	24.7	26.9	29.1	31.4	33.6	35.8	38.0	40.3
1.00	9.9	12.1	14.4	16.6	18.8	21.0	23.2	25.5	27.7	29.9	32.1	34.4	36.6	38.8	41.0
1.10	10.7	12.9	15.1	17.3	19.6	21.8	24.0	26.2	28.5	30.7	32.9	35.1	37.3	39.6	41.8
1.20	11.4	13.7	15.9	18.1	20.3	22.6	24.8	27.0	29.2	31.4	33.7	35.9	38.1	40.3	42.6
1.30	12.2	14.4	16.7	18.9	21.1	23.3	25.5	27.8	30.0	32.2	34.4	36.7	38.9	41.1	43.3
1.40	13.0	15.2	17.4	19.6	21.9	24.1	26.3	28.5	30.8	33.0	35.2	37.4	39.7	41.9	44.1
1.50	13.7	16.0	18.2	20.4	22.6	24.9	27.1	29.3	31.5	33.8	36.0	38.2	40.4	42.6	44.9

Encourage the design team to identify all applicable PPL strategies. The PPL champion must encourage 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. This strategy increases the ratio of occupant use per building area or piece of equipment. By implementing space efficiency, the amount of equipment in the building is decreased. Breakrooms, common print areas, and cafeterias typically have dense PPLs. With increased space efficiency, the number of these areas is decreased, equipment is more efficiently utilized, 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. For example, wall switches were installed in the RSF coffee kiosk to cut power to controlled outlets during unoccupied hours.

The design team is typically responsible for specifying equipment such as elevators and transformers. Before elevators are specified, the stairs should be designed to be as inviting and convenient to use as possible. Elevators should then be carefully scrutinized to find the most efficient model. Some important features to look for are reduced speed, occupancy sensor-controlled lighting and ventilation, and smart scheduling. Some projects may require the design team to specify general appliances such as refrigerators, dishwashers, and drinking fountains. To achieve greater energy savings, the most efficient equipment models must be specified.

Another PPL the design team is responsible for is process cooling systems for areas with concentrated plug loads (such as data centers and IT closets). These systems should use, where applicable, economizers, evaporative cooling, and waste heat recovery. In data centers, energy use can be further reduced through hot and cold aisle containment, which allows cold air supply temperatures to be higher than usual; thus reducing the process cooling load. The RSF data center uses all these efficiency measures to meet the low energy goal.

Institutionalize plug load measures through procurement decisions and policy programs. 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 designing a low energy building is to institutionalize PPL measures through procurement decisions and policy programs. To do this, the champion must identify decision makers who can institutionalize programs based on identified PPL efficiency measures. These peoples' expertise is critical to promote buy-in and identify unbreakable and unchangeable policies.

Address unique miscellaneous PPLs. Some equipment is not specified by the design team, modeling team, occupants, or building owners. For example, contractors typically control food service areas. For such situations, the building owner can contractually require or provide the most efficient equipment available.

Energy-efficient gym equipment and ATMs may not be available and may be restricted from being turned off. These particular PPLs must be addressed on a case-by-case basis. Manufacturers may be able to recommend alternatives.

Occupant awareness. The last step in designing PPLs for a low energy building is to promote occupant awareness of efficiency measures and best practices. The occupants should be encouraged and allowed to "do good;" however, PPL management strategies should be designed to counteract "bad users." They should also be educated about the energy ramifications of leaving personal electronics running when they leave their workspaces.

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This paper documents the design and operational plug and process load energy efficiency measures needed to allow a large scale office building to reach ultra high efficiency building goals. The appendices of this document contain a wealth of documentation pertaining to plug and process load design in the RSF, including a list of equipment was selected for use.

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