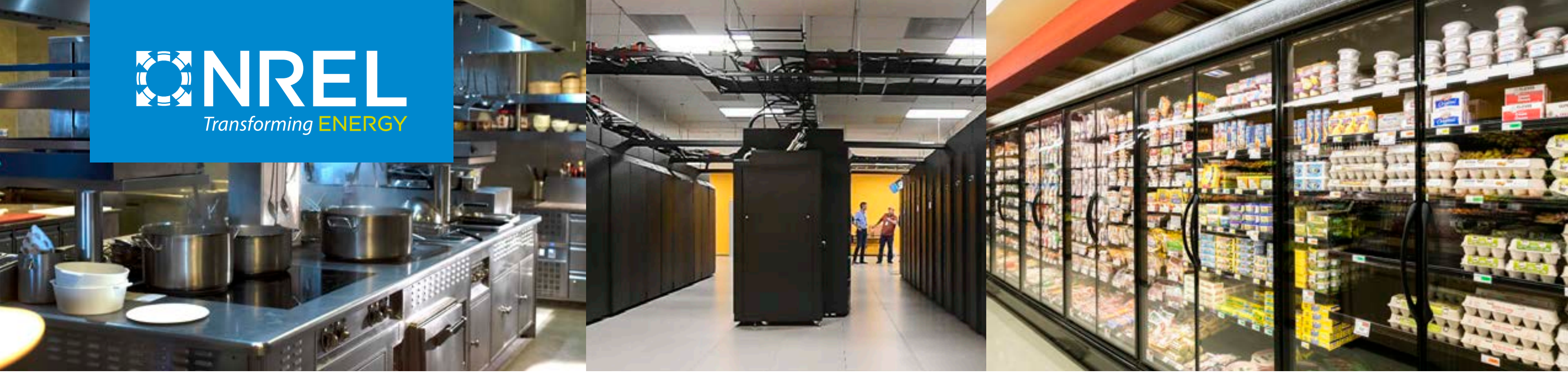

Reducing Commercial Building Process Loads and Refrigeration Unit Energy Consumption

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.

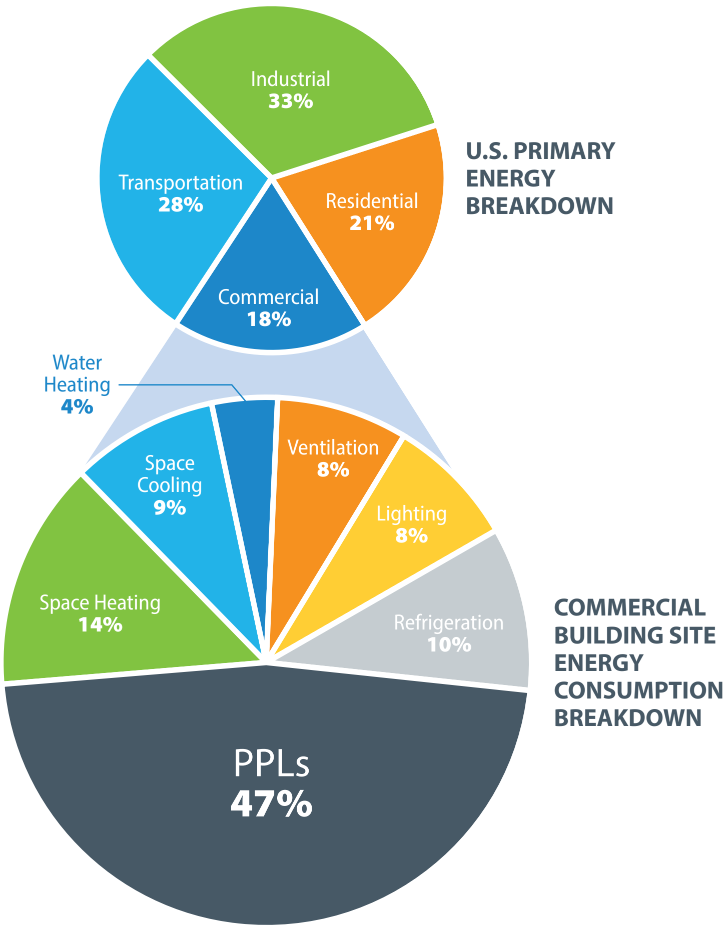

Figure 1. Plug and process loads (including refrigeration) account for 57% of commercial building energy consumption. *Graph by Kristi Maisha, NREL; Data source: EIA (2020)*

[1] PPL energy consumption includes data from four of the Energy Information Administration's Annual Energy Outlook end-use categories: cooking, computing, office equipment, and other uses. "Other uses" includes, but is not limited to, miscellaneous uses such as medical equipment, elevators, escalators, laboratory fume hoods, laundry equipment, and emergency generators.

Assessing Process Loads

Assessing a building's process loads provides an estimate of its energy consumption and is done through inventory and metering.

Inventory

Begin with a walk-through to take an inventory of process loads in the building. The goal of the walk-through is to determine device and equipment energy 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). The walk-through is also an opportunity to identify obsolete equipment and unused devices that can be removed.

Metering

Metering can help identify the process loads with the highest potential for energy reduction. Many of the newer process loads can self-monitor and report their energy consumption, and those data could be exported periodically for further analysis. Depending on the equipment's capabilities, the data can be very limited and time-based detailed parameters may be missing. For more detailed data, the most common methods of metering process loads include digital power meters, smart outlets, and circuit-level submetering. Plug-in digital power meters (Figure 2a) and smart outlets (Figure 3) offer quick and easy ways to measure the electrical consumption of plug-in loads.

For hardwired loads, circuit-level submeters are available as permanent (Figure 2b) or temporary (Figure 2c) installations. Temporary submeters, like energy analyzers and loggers, are designed to meter a building's load for a short period of time and are removed after the metering study has concluded. Voltage taps and current transducers for this setup are typically installed either at electrical distribution panels, gutters, or switchboards, whichever provides the easiest

(a) (b) (c)

Figure 2. (a) Example plug-in digital power meter. *Photo from iStock 175484325;* (b) Example permanent circuit-level power meter. *Photo from iStock 153688187;* (c) Example temporary circuit-level meter. *Photo iStock 111905131.*

and safest access point to the circuit wiring. As the name suggests, permanent submeters are permanently installed hardware for circuit measurement and will continue to provide energy data beyond the initial process load metering. The data are stored in a logger and/or can be transmitted to various platforms including cloud-based platforms for virtual access. Within the platform, the granular data can be used to identify device-level trends or aggregated to show system-level energy insights. Depending on the local codes, a qualified and licensed electrician may be required to install the submetering setup, because the process may require working with exposed wiring.

To account for the day-to-day change in energy consumption, it is recommended that process loads be monitored for at least 2 weeks.

Disaggregated Metering

Consider using a disaggregated metering approach as outlined in Doherty and Trenbath (2019) if the building includes more than one of the same type of process loads. This involves metering only one of the pieces of equipment and using the data to extrapolate the energy use of all equipment of the same kind within the building.

Choosing Targets

Use the energy and inventory data collected during the metering process and walk-through to determine (1) the loads that consume large amounts of energy and (2) the equipment and appliances with the highest counts in the building. These are loads that could have the highest potential for energy savings and could be targeted for energy reduction. One way to determine the potential savings of a device is to compare its energy consumption to that of a more efficient model. More detail about efficient process loads can be found in the Upgrading to Energy-Efficient Equipment and Equipment Consolidation section. To increase energy savings further, or if a more efficient model is not available, consider implementing a reduction technology or strategy as described in the following section.

Common Energy Reduction Technologies and Strategies

There are several reduction technologies and strategies that are applicable to a wide variety of process loads. These are described in the following subsections. Following this discussion, the Reducing Process Load Energy Consumption section provides details on which of these technologies and strategies are best suited for each process load category, as well as additional considerations for each category.

Schedule-Based Control

Smart Outlets

Smart outlets are wireless meter and control devices (Figure 3). They fit between the receptacle and device plug and control whether electricity flows to the device. Smart outlets can

Figure 3. Plug-in smart outlet. *Photo from WattIQ.*

be programmed with a specific control schedule and can automatically switch off power to devices plugged into them at certain times during the day. These controls can also be applied and changed remotely through online software. More information can be found in Smart Outlets: Wireless Meter and Control Systems for Plug and Process Loads.

Timers

Turning off devices when they are not in use can save significant energy. Timers can shut devices down automatically after a given period of time or at a certain time of day. Process loads that do not come with integrated timers must use an external timer.

Occupancy Control

Controllers with occupancy sensors power down process loads or their components automatically when a space is no longer being used. Process loads can also respond to an unoccupied signal by reducing their energy consumption while maintaining their function. For example, some escalators will slow when the space is at low occupancy. Many process loads come with integrated occupancy or motion sensors. Those that do not can be retrofitted with an external sensor to control the load.

Built-In Low-Energy Operation

It is increasingly common for process loads to be equipped with low-energy operating modes. These are often given intuitive names, such as "low-power" or "eco-mode," but others can be less straightforward. For example, some commercial dishwashers offer several different wash cycles depending on how difficult the dishes are to clean. In this example, selecting the shortest cycle and lowest temperature for the job will minimize energy consumption. Additionally, process loads such as information technology (IT) equipment and elevators commonly feature a standby mode. Check the equipment operational manual or consult the manufacturer to see whether a process load includes a built-in standby mode, and ensure this capability is enabled. It is important to coordinate with your information services department to ensure software updates can be made while process loads are in low-energy mode to maintain effective business operations (Schantz and Langner 2016).

Upgrading to Energy-Efficient Equipment and Equipment Consolidation

Upgrading appliances or equipment to more efficient models is an effective way to reduce a building's process loads. Figure 4 shows the potential savings of upgrading process loads commonly found in commercial buildings to more efficient models. A good starting point is to procure ENERGY STAR®-certified or better equipment. Other resources exist to identify energy-efficient equipment, such as those published by the Consortium for Energy Efficiency. Many utilities offer incentives for installing energy-efficient equipment; check with your utility for a list of available incentives and rebates

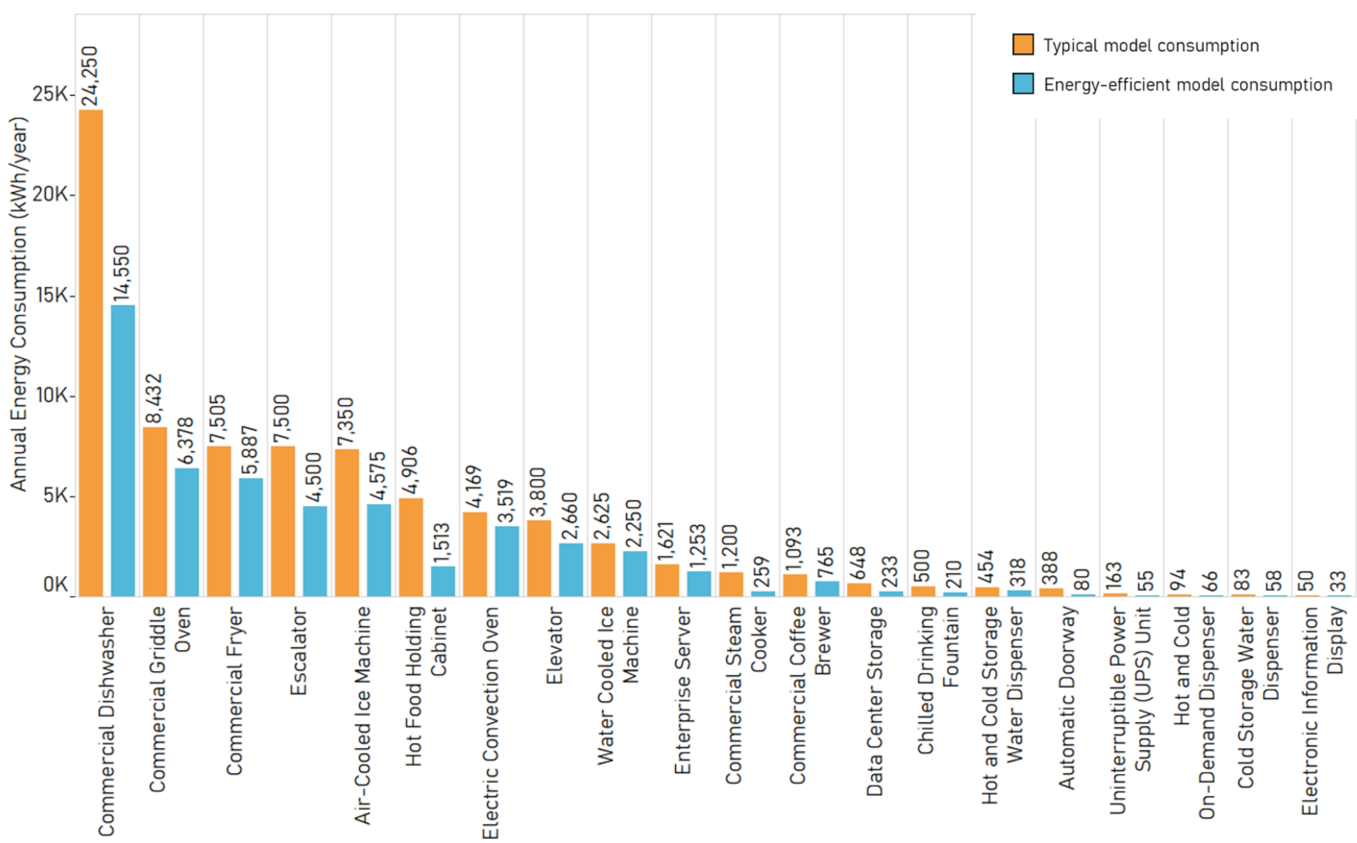

Figure 4. Energy consumption of typical devices, appliances, and equipment found in commercial buildings versus energy-efficient models. *DOE 2021; Shen Rastogi 2010; Shen Rastogi 2009*

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. One way to integrate the newer efficient technology is to retrofit individual components within the equipment. Retrofits can be as simple as one-to-one replacement or can involve a complete overhaul of all components in the equipment. For example, if display lights are older generation fluorescent or incandescent bulbs, or LEDs, they can be upgraded with new LED lights, which have the added benefit of improving display lighting. Old motors in process loads can be upgraded to premium efficiency motors along with adding advanced variable frequency drive controls to achieve substantial energy savings. Check for retrofit rebates offered by your local utility.

Although it is common to wait until an appliance or piece of equipment has reached the end of its life before replacing it, an earlier replacement could be economical if the appliance or equipment is many technology generations behind the 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]

Equipment consolidation is another strategy for achieving energy savings. During the inventory process, consider whether the function of many process loads could be handled by fewer pieces of equipment or devices. For example, multiple fryers used at only part capacity could be consolidated to a fewer number that still meets the demand.

Maintenance and Behavior

Maintaining process load equipment can not only ensure longevity, but also keeps equipment and devices operating efficiently. Following a proper maintenance schedule can reduce process load energy consumption.

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

[2] Circular economy is a systems solution framework that aims to eliminate waste and pollution, circulates products and materials, and is regenerating in nature. More detail from the U.S. Environmental Protection Agency: https://www.epa.gov/recyclingstrategy/what-circular-economy.

Table 1. Common Energy-Saving Strategies for Each Process Load Category

Category	Typical Connection	Example Loads	Common Energy Saving Strategies					
			Schedule-Based Control	Occupancy Control	Built-In Low-Energy Operation	Upgrade to Energy Efficient Equipment	Maintenance and Behavior	Design Strategies
Food Handling	Plug-in & hardwired	Dishwashers, hot food holding, fryers			●	●	●	●
Refrigeration	Plug-in & hardwired	Refrigerators, freezers, walk-ins, ice machines	●	●		●	●	
Internal Mobility	Hardwired	Elevators, escalators, moving walkways		●	●	●	●	●
Data Center and Information Technology	Plug-in & hardwired	Enterprise servers, network switches, data storage systems		●	●	●	●	●
Water Handling	Plug-in	Water coolers, fountains, wastewater handling	●	●	●	●	●	

off equipment and devices when not in use and to enable sleep settings when possible. Additionally, if a schedule- or occupancy-based control system has been installed in the building, educate occupants on what the system is and how to interact with it to maximize the system's effectiveness.

Building Design Strategies

When designing or retrofitting a building or space, identify opportunities for process load energy savings through energy-efficient design. For example, arrangement of food handling equipment, such as stoves, has a significant impact on exhaust fan energy consumption. Reference ASHRAE's Zero-Energy K-12 School Advanced Energy Design Guide for detailed energy-efficient design recommendations.

Reducing Process Load Energy Consumption

Table 1 provides an overview of common process load energy-saving strategies and the categories for which they are applicable. Many utilities offer rebates for installation of process load control technologies and retrofits. Check with your utility for a list of available incentives and rebates, or download a list of incentives from the Better Buildings Alliance PPL website listed under Policies and Incentives. The subsequent sections provide more detail and considerations for each category.

Food Handling

Process loads in the food handling category include commercial equipment such as dishwashers, hot food holding, and fryers. The primary method for reducing energy consumption in this category involves procurement. Energy savings can be achieved either by replacing equipment with a more efficient model of the same type or a more efficient type of equipment. For example, convection ovens can significantly reduce cook time compared to conventional ovens and therefore achieve energy savings. Another example is replacing high-temperature dishwashers with heat recovery dishwashers.

Factors such as maintenance and behavior also play a role in food handling energy consumption. Turn equipment off when not being used, and follow a proper maintenance schedule to ensure equipment is operating efficiently. Institute a start-up and shutdown schedule for all cooking and holding equipment and maximize dishwasher loading for each cycle.

Identify opportunities for food handling energy savings during the kitchen design process, whether new or retrofit. Position heavy-duty equipment, such as underfired broilers or wok ranges, in the middle of the cook line, and locate double-stacked ovens or steamers at the end of the exhaust hood as a plume control effect to achieve ventilation energy savings (Better Buildings Initiative 2021i).

For more detailed recommendations, reference the kitchen section in ASHRAE's Zero-Energy K-12 School Advanced Energy Design Guide, the equipment section of the Low Carbon Technology Strategies Commercial Kitchen resource, or reach out to the kitchen experts at Frontier Energy.

Refrigeration

The primary way to reduce the energy consumption of refrigeration units is to upgrade to a more efficient model or replace components. Figure 5 breaks down the typical variance in the energy consumption among different types of refrigeration cases used in commercial buildings. Ultra-low temperature freezers offer the highest potential savings (over 4,600 kWh/year) by upgrading to an energy-efficient model. Consider replacing glass door units with solid door models as they can achieve up to 345 kWh/year and 1,200 kWh/year in savings over glass door refrigerators and freezers, respectively. Open display cases consume nearly as much energy as freezers and should be replaced with closed-door models.

For walk-in refrigeration units, consider increasing the temperature set point when possible. ENERGY STAR® recommends maintaining a refrigeration temperature of 35 – 38°F (ENERGY STAR n.d.-a). Additionally, airflow into and out of the unit can be reduced by installing automatic doors, strip curtains, and doors that latch and seal when closed. Occupancy sensors should be utilized to turn off lights in walk-ins when not in use (Better Buildings Initiative 2021). Refrigeration equipment such as ice machines are good candidates for timers, which can be applied to keep the machine off once it has made enough ice or restrict operation to off-peak utility hours.

In buildings where mini refrigerators exist (i.e., office buildings), determine whether several are going unused and could be replaced with a larger, efficient unit that serves multiple occupants.

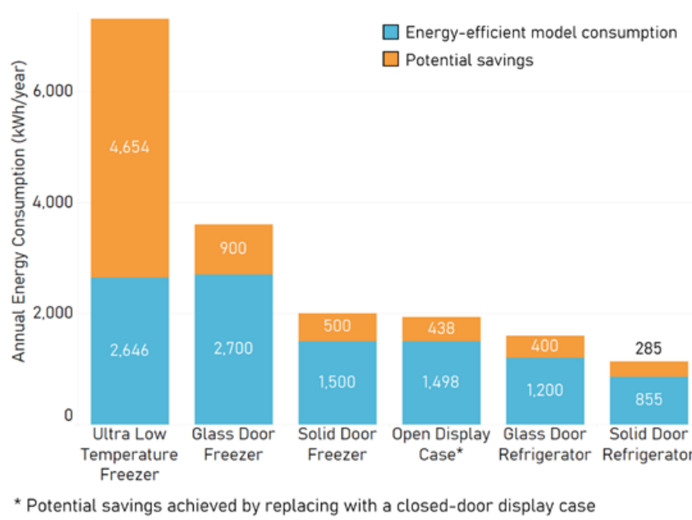

Figure 5. Energy consumption of typical refrigeration units and potential savings from upgrading to more efficient models. *ENERGY STAR n.d.; FEMP n.d.; Fricke and Becker 2010*

Additional considerations in this category include transitioning to energy-efficient and lower global warming potential refrigerants, upgrading fixed-speed compressors to variable-capacity compressors, and updating the unit's controller for advanced energy management capabilities.

Internal Mobility

Internal mobility refers to technology that is used to assist with movement within commercial buildings, such as elevators, escalators, and moving walkways. Energy reductions can be achieved through upgrading equipment, enabling low-energy operation modes, and installing occupancy sensors. Efficient elevator technologies on the market today include permanent magnet gearless drives with regeneration and advanced destination dispatch software to optimize the elevator's operation (Sachs, Misuriello, and Kwatra 2015). Many models also offer a standby mode, which turns off lights, music, and cab ventilation systems when the elevator is not in use. If an elevator in your building does not have built-in standby mode features, install an occupancy sensor to power down cab lights and ventilation systems during times of prolonged vacancy.

Design for and install escalators and moving walkways with energy-efficient operating modes, such as eco-mode, to allow them to slow their speed when traffic is low (Hitachi n.d.; KONE n.d.). For escalators and moving walkways without this built-in capability, install occupancy or motion sensors that communicate with the equipment's variable frequency motors via a wired connection to enable them to be stopped or slowed when not being used and draw less power when not at full occupancy. For all equipment in this category, replace lighting with LEDs.

During the building design or retrofit process, look for ways to minimize internal transportation energy consumption. For example, design the location of stairs such that occupants are encouraged to use them over escalators or elevators (e.g., placing the stairs so that they can easily be viewed from entrances).

Many of these recommendations are included in ANSI/ASHRAE/IES 90.1 (ASHRAE 2019a), California Title 24 (CA Title 24 2019), and IECC (IECC 2021) building energy codes and could be required in your jurisdiction.

Data Centers and Information Technology

Process loads in the data center category include enterprise servers, IT equipment, uninterruptible power supply (UPS) units, and mass data storage systems. Many of the recommended strategies for this category revolve around maintaining the proper temperature for the central processing units (CPUs) in the data center. For air-cooled systems, install variable speed fans or switch to a liquid-cooled system for further energy savings. Additionally, data centers are often conditioned to a lower temperature than necessary, resulting in higher cooling energy consumption. At minimum, follow ANSI/ASHRAE Standard 90.4 guidelines for data center temperature ranges, but consider operating at the maximum allowable range as specified in the standard (ASHRAE 2019b). Depending on the equipment class, maximum temperature recommendations range from 89 – 113°F. Consider recovering heat produced by the CPUs in the data center to be used for other purposes, such as to heat other spaces within the building. A data center's layout also plays a key role in its energy consumption. Installing racks in rows and implementing hot and cold aisles can improve data center energy efficiency. Use the standard energy performance metrics for data centers, such as power usage effectiveness (PUE), to provide an indication of and track data center efficiency. Consider moving your data center needs off-site and take advantage of cloud computing services. Cloud facilities are often run more efficiently and will result in energy savings.

For IT equipment, consider server consolidation, decommissioning, and virtualization to achieve energy savings. Additionally, procure energy-efficient equipment such as ENERGY STAR-certified UPS systems during an IT refresh. Some systems on the market feature an eco-mode that improves the efficiency of the UPS by bypassing the inverter or rectifier and directly feeding the load. Consult your UPS provider to determine whether eco-mode is appropriate for use in your facility. Additionally, UPS system efficiency drops significantly at low load factors.[3] Consider installing lower capacity or modular UPS systems to improve efficiency and reduce energy consumption (ENERGY STAR n.d.-c).

For more detailed data center strategies, reference the Center of Expertise for Energy Efficiency in Data Centers toolkit, the Better Buildings Alliance Data Center Accelerator toolkit, and ENERGY STAR's recommendations for avoiding energy waste in data centers.

Water Handling

Process loads in the water handling category include equipment such as hot- and cold-water dispensers, drinking fountains, systems for supplying and pressurizing drinking water supply, wastewater handling, sump pumps, and fire suppression. Beyond replacing equipment with a more energy-efficient model, consider installing timers on drinking fountains to power them down during unoccupied hours. In northern climates, adjust the drinking fountain to an acceptable warmer temperature to achieve additional savings. Along with retrofitting the water supply pumps with more efficient motors and variable speed drives, regular maintenance of supply system components can result in long-term energy savings.

3 Load factor is a measure of how much of a UPS system's capacity is being used, on a scale from zero to one. The nearer the load factor is to one, the higher the system's efficiency.

Advanced Strategies

Technology related to process loads is frequently being updated, with new features becoming available regularly. Energy efficiency may not be a high priority for product development although manufacturer equipment offerings are becoming more advanced. Table 2 summarizes advanced strategies, which require more work from the purchaser but will improve the energy efficiency of products and equipment on the market.

Table 2. Advanced Strategies

Category	Recommendation	Details
Procurement and Strategic Sourcing	Procure equipment that is ENERGY STAR certified.	If no ENERGY STAR equipment is available, contact ENERGY STAR and encourage them to consider the equipment category for their next set of specifications.
	Strategically source equipment that has sleep settings or low-power modes.	According to the California Plug Load Research Center, many sleep settings do not actually reduce the power consumption of a device. Ask manufacturers to ensure that "sleeping" devices use significantly less energy than while in use. Additionally, ask manufacturers to make low-power and sleep-enabled modes the defaults at installation or ensure they are enabled out of the box.
	Strategically source equipment with built-in timers, occupancy sensors, and controls to enable sleep and low-power modes.	If none are available, ask manufacturers to include these features in future iterations of their products.
Specification	Develop energy-efficient design specifications.	Develop equipment specifications that meet the building's or organization's goals for equipment energy consumption. This can be done individually or with a consortium or team. Institute a formal procurement process that includes the specification in requests for proposal or requests for information. During the request for proposal or request for information process, use the specification to ensure that manufacturers understand your energy efficiency goals. (Note: the manufacturer might not have an existing product that meets the procurement specification. To respond to the request, they will need to develop a piece of equipment that meets the specification[s]).
Outreach	Communicate energy efficiency goals to manufacturers.	Use opportunities in addition to procurement to communicate goals. Examples include during sales meetings, trade shows, and conferences.
	Communicate energy efficiency goals to industry groups.	Communicate goals to industry groups such as the Better Buildings Alliance and build interest among commercial building professionals whenever possible.

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