Selecting a Control Strategy for Miscellaneous Electrical Loads

Chad Lobato, Michael Sheppy, Larry Brackney, Shanti Pless, Paul Torcellini
National Renewable Energy Laboratory
Golden, Colorado

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Executive Summary

Background

Miscellaneous electrical loads (MELs) are building loads that are not related to general lighting, heating, ventilation, cooling, and water heating, and typically do not provide comfort to the occupants. MELs in commercial buildings account for almost 5% of U.S. primary energy consumption (McKenney et al. 2010). On the building level, they account for approximately 25% of the total electrical load in a minimally code-compliant commercial building, and can exceed 50% in an ultra-high efficiency building such as NREL's Research Support Facility (RSF) (Lobato et al. 2010). They also impact the heating and cooling loads of buildings because of the heat they produce. Minimizing MELs is a primary challenge in the design and operation of an energy-efficient building.

A complex array of technologies that meter and control MELs has emerged in the marketplace. NREL has developed guidance for evaluating and selecting MELs controls, and is using this process to evaluate a range of technologies. Using control strategies to match MELs energy use to user work schedules will result in great energy savings. This procedure is replicable; most commercial buildings can realize energy savings through MELs control.

Results

We evaluated MELs and related control strategies to ensure that the RSF would meet its energy goals. These results were distilled into a flowchart (see Figure 2–1 through Figure 2–4) so others could implement and achieve similar savings based on our experiences. The flowchart asks a series of questions about a MEL's use and specifies its appropriate control strategy. It helps to identify deficiencies in the equipment and highlights when the equipment or process could be adapted to a more efficient approach. The chart also points out key areas where equipment manufacturers could improve their products to reduce energy consumption.

Results from the baseline measurements of uncontrolled workstations in the RSF highlight the importance of encouraging "good" user behavior. Ideally, all MELs control strategies would counteract "bad users," but not all are "user proof." Educational programs that encourage "good" user behavior should be implemented along with these strategies wherever possible.

How To Use This Document To Choose a Cost-Effective Control Device

Figure ES–1 will take you through a step-by-step process to address and control MELs in a cost-effective way.

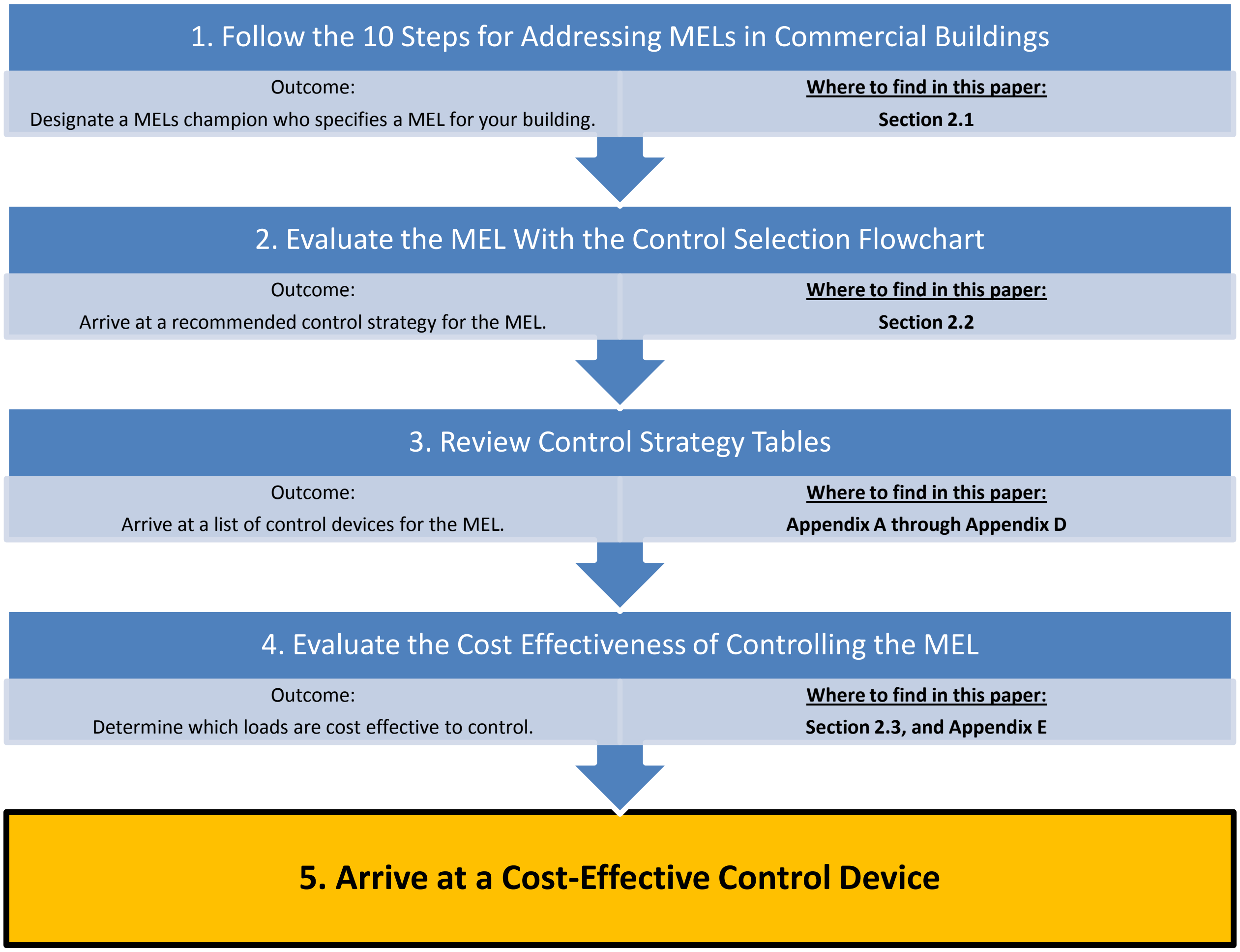

Figure ES–1 Steps to effectively control MELs
(Credit: Michael Sheppy/NREL)

Nomenclature

BMS	building management system
DOE	U.S. Department of Energy
EUI	energy use intensity
ft^2	square feet
Hz	hertz
in.	inch
IS	Information Services Office
kBtu	1000 British thermal units
kW	kilowatt
kWh	kilowatt-hours
LCD	liquid crystal display
LED	light emitting diode
MEL	miscellaneous electrical load
NREL	National Renewable Energy Laboratory
PV	photovoltaics
RSF	Research Support Facility
UPS	uninterruptible power supply
USB	universal serial bus
V	Volt
W	Watt

Contents

Figures and Tables

Figures

Tables

1.0 Introduction

Miscellaneous electrical loads (MELs) in commercial buildings account for almost 5% of U.S. primary energy consumption (McKenney et al. 2010). They account for 25%–30% of the total electrical load in a minimally code-compliant commercial building, and can exceed 50% in an ultra-high efficiency building such as the National Renewable Energy Laboratory's (NREL) Research Support Facility (RSF) (Lobato et al. 2010).

The percentage of total building energy use from MELs is increasing. By 2030, commercial building energy consumption is expected to increase by 36%, while MELs energy consumption is anticipated to increase by 78% in the same time frame (U.S. DOE 2009). The disproportionate growth of MELs energy consumption compared to whole-building energy consumption is due to a combination of several trends. Other building end uses, such as lighting and mechanical systems, are becoming more efficient. MELs are becoming increasingly important for business activities, their installed equipment densities are increasing, and their prices tend to decrease over time making them available to a larger range of users (McKenney et al. 2010). These trends illustrate the importance of MELs energy reduction to achieve an overall goal of reducing whole-building energy consumption.

Traditionally, the design community has not viewed MELs as an integral building system, but as a necessary evil. The designers have simply worked around the issue rather than address it. Reducing and controlling these loads is a primary challenge in the design and operation of an energy-efficient building.

At the beginning of the RSF project, the goal was to use less than half the energy of a conventional building. MELs reduction and control would clearly be required. Between the owner and the design team, a 50% reduction in MELs was required (Lobato et al. 2010). The NREL RSF energy targets are shown in Figure 1–1:

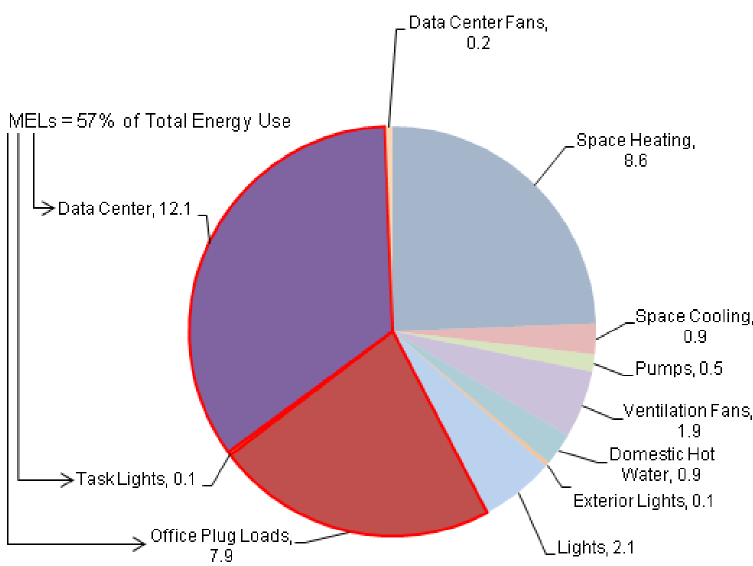

Figure 1–1 RSF annual energy use breakdown targets (kBtu/ft^2)
(Credit: Chad Lobato/NREL)

Many methods were available to reduce MELs energy use in the RSF:

- Reduce the number of MELs.
- Specify energy-efficient MELs.
- Turn off MELs when not in use:
    - Through technology (e.g., MELs control power strips)
    - Through behavior changes (e.g., user engagement and involvement).

This report addresses all these methods. Our primary focus is to enable readers to select cost-effective control devices for MELs in their buildings.

An array of technologies that meter and control MELs has emerged in the marketplace. NREL has developed guidance for evaluating and selecting MELs control technologies, and is using this guide to evaluate the range of technologies that turn off MELs when not in use.

For many uncontrolled MELs, a significant portion of their energy use is from parasitic loads, which are generally defined as a MEL's power draw in an "off" state. We define a parasitic load as the power draw of a device that is not performing useful work. This is broader than the traditional definition because it includes all MELs, in any state, that are not performing useful work. All parasitic loads result in wasted energy and should be transitioned into the lowest power state possible.

MELs are driven primarily by user behavior. Occupants in office buildings are typically seated at their desks for less than one third of the average workday (U.S. General Services Administration 2006). And more than two thirds of the year consists of nonbusiness hours when users are not in the workplace. This equates to a maximum use time for some office MELs of approximately 10% of the year. Using control strategies to match MELs energy use to user work schedules will result in great energy savings.

MELs are diverse, and span a wide range of equipment types. They provide multiple functions and services and are operated in many ways. The same MEL type may have completely different use patterns from one location to another. Thus, control strategies must be tailored to the individual MELs. Currently, no single commercially available control device can control all MELs properly. Manufacturers market their control devices as the solution to MELs energy use, but do not specify where they are applicable. Building owners and occupants may believe these devices control all loads effectively, but they are uninformed about which strategy should be used for which MEL. Some MELs can be effectively controlled with inexpensive scheduling devices such as electrical outlet timers; others require much more complicated solutions that may incorporate multiple control strategies.

An in-depth analysis of the equipment and process is needed to arrive at the correct control strategy for a given MEL. The required MELs can then be specified and the corresponding control strategy determined and implemented. This report describes the process required to achieve cost-effective MELs energy savings and describes lessons learned for others to achieve similar savings levels.

2.0 Guide to Addressing and Controlling Miscellaneous Electrical Loads

The following sections describe the complete process required to achieve MELs energy savings. This process can be applied to new construction, retrofits, and day-to-day operations to ensure MELs energy reduction and to achieve an overall goal of whole-building energy reduction.

2.1 Addressing Miscellaneous Electrical Loads

To achieve the maximum MELs energy savings in your building, you must undertake an aggressive MELs benchmarking, specification, and procurement process. This will reveal which MELs are currently in your building and how they are used, and will help you outfit the building with energy-efficient equipment and ensure its efficient operation.

The following steps should be taken to achieve MELs energy savings. Control strategies should then be implemented to achieve further energy savings.

2.1.1 Establish a Miscellaneous Electrical Load Champion

A MEL champion (or a team of champions) will initiate and help with these strategies. 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.

Often, MELs are not thought of as an integral building system so they are viewed as a necessary evil. MELs 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 MELs and that they make decisions that save energy and integrate well with other building systems.

2.1.2 Benchmark Current Equipment and Operations

A building walkthrough to identify and inventory MELs will establish a baseline of 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 portfolio wide.

2.1.2.1 Perform a Walkthrough

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

For a detailed example of how a MEL walkthrough is conducted, refer to Frank et al. (2010).

2.1.2.2 Develop a Metering Plan

The champion will then develop a metering plan. Common items require only a representative sample to be metered. For example, if every occupant uses the same type of computer monitor, only a small sample needs to be metered. The MELs 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 MEL power meters. If this is not possible, either because the MELs are hard-wired to the electrical system or because their voltage and current requirements are too great, manufacturer nameplate data can be used to determine power draw. This can then be multiplied by the hours of use to derive an estimate of actual energy use. Once the data from the walkthrough are collected and analyzed, they can be used to understand when equipment is operated and highlight opportunities to turn off the equipment when it is not needed.

2.1.2.3 Select a Power Meter

The first step in metering plug loads is to select the meter. A meter that can measure and log electrical power (W) data at a sampling interval of 30 seconds or faster for a week or more is desirable. This metering interval and period should provide sufficient data to get a representative sample of the MEL's power draw in all power states. A meter that cannot log the measured data and that provides only instantaneous measurements will still offer valuable information, but the accuracy of the power draw profile over an extended period will be affected.

The meter should be designed for the type of circuit to be metered (typically 120 V, 15 amp, 60 Hz in the United States). Also, MELs are numerous and varied, so the meter should be able to accurately meter loads of 0–1800 W (or greater for some larger MELs). Other desirable features include an external display, an internal clock that time stamps each data point, an Underwriters Laboratories listing, and a way to transmit data to a local or remote repository. A more detailed meter specification list was developed by Frank et al. (2010).

2.1.2.4 Meter the Miscellaneous Electrical Loads

The steps to execute the metering plan for a given MEL 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. Determine whether the MEL can be de-energized to install the meter.
    a. Some MELs cannot be de-energized because of:
        - Health and safety concerns
        - Interruption to business operations
        - Reduction in sales
        - Shutdown procedures
        - Reconfiguration requirements on startup.

    b. If the MEL cannot be de-energized, use manufacturer nameplate data to estimate the device's in-use power draw. Observe and note the MEL's use pattern to estimate the device's energy use.
3. If a business function will be interrupted by installing the meter, consider waiting until nonbusiness hours to do so.
4. If applicable, install any necessary computer software so the meter can be configured and the measured data can later be downloaded and analyzed.

5. Set up the meter to measure electrical power at a sampling interval of 30 seconds.
6. Power down and unplug the device to be metered.
7. Plug the device into the meter. Plug the meter into an outlet.
8. If necessary, clear the memory on the meter and go through any other initial setup, such as setting the date and time.
9. Power on the device.
10. 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.
11. Download the metered data for analysis. Calculate the average load during business and nonbusiness hours.

2.1.3 Develop a Business Case for Addressing Miscellaneous Electrical Loads

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

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 MEL reduction strategy, so nonenergy benefits should be highlighted. For example, it is often difficult to justify purchasing best-in-class laptop computers with energy cost savings alone. Laptops can be justified, however, because they enable work from home and travel mobility. If mobility is not necessary, mini-desktops are available that have the efficiency of a laptop without their added costs and security concerns.

Another example is centralized multifunction devices, which can reduce maintenance costs and unique toner support over individual printers, copiers, and fax machines. Minimizing, centralizing, and standardizing document services greatly increase the ease of implementing 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.

For projects such as the RSF with net-zero energy goals, one powerful strategy is the avoided cost of renewables metric. This equates the cost of MEL efficiency measures to avoided renewable costs. To meet the RSF's net-zero energy goals, we used this metric to justify many of the demand-side efficiency measures, including MELs procurement and control decisions. The project's economics were such that the annual energy use of a continuous 1-W load required $33 worth of photovoltaics (PV) to meet the demand. The PV cost avoided by MEL reductions exceeded $4 million.

2.1.4 Identify Occupants' True Needs

Identify occupant 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 MELs, 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 MELs 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 occupant demand and eliminate numerous personal coffee makers.

2.1.5 Meet Needs Efficiently

Once the list of true needs is determined, each must be met as efficiently as possible. Specifying ENERGY STAR® and EPEAT® equipment is a good start, but alone will not maximize cost-effective energy savings. These databases should be thoroughly reviewed and the most efficient equipment specified. 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 MELs' 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.

2.1.6 Turn It All Off

Office buildings are unoccupied for 66%–75% of the hours in a year. A key step in any MELs reduction program is to reduce energy use during unoccupied hours, as this is generally wasted. Details about how to reduce energy use during unoccupied hours are provided in Sections 2.2 and 2.3.

Table 2–1 shows the annual plug load energy use intensity (EUI) for a given average daytime and nighttime power density. (The table was developed assuming 9 occupied hours per work day and 250 work days per year.) Minimizing nighttime MELs significantly reduces the annual EUI. The area outlined in red shows the targeted MELs densities and EUIs for the RSF, excluding the data center. Daytime MELs were modeled to be about 0.50 W/ft^2; nighttime MELs were modeled to be about 0.19 W/ft^2.

Table 2–1 Annual MELs EUI in kBtu/ft²·yr Based on Day and Night Power Densities

		Nighttime Power Density (W/ft²)											
		0.10	**0.20**	**0.30**	**0.40**	**0.50**	**0.60**	**0.70**	**0.80**	**0.90**	**1.00**	**1.10**	**1.20**
Daytime Power Density (W/ft²)	**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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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
	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

2.1.7 Institutionalize Miscellaneous Electrical 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 MELs energy use is to institutionalize MEL measures through procurement decisions and policy programs. To do this, the champion must identify decision makers who can institutionalize programs based on identified MEL efficiency measures.

2.1.8 Address Unique Miscellaneous Electrical Loads

Some equipment is not specified by the building owner or occupants. 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.

Some miscellaneous items such as energy-efficient gym equipment and automated teller machines may not be available and may be restricted from being turned off. Such MELs must be addressed on a case-by-case basis with manufacturers to identify any possible solutions.

2.1.9 Promote Occupant Awareness

A crucial step in MELs control is to promote occupant awareness of efficiency measures and best practices. Occupant awareness can come in such forms as:

- Training
- Informational letters
- Emails
- Signage
- Videos

- Periodic reminders or updates.

The occupants should be encouraged and allowed to “do good”; however, MELs control strategies should be designed to counteract “bad users” by turning off equipment when not in use. Users should also be educated about the energy ramifications of leaving personal electronics running when they leave their workspaces.

2.1.10 Address Miscellaneous Electrical Loads (Design Team)

New construction and retrofit projects bring additional MELs 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 MELs is maximizing space efficiency, which increases the number of occupants who use a building area or piece of equipment. Increasing space efficiency decreases areas of dense MELs, such as break rooms, common print areas, and cafeterias. Equipment in these areas is more efficiently used, and MELs are reduced.

The design team has the opportunity to further reduce energy use by integrating MELs 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 (BMS).

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 as possible. Elevators should then be carefully scrutinized to find the most efficient model. Some important features to look for are reduced speed, occupancy-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.

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

2.2 Controlling Miscellaneous Electrical Loads

2.2.1 Available Control Strategies for Miscellaneous Electrical Loads

MELs control comes in two basic forms. The device is either transitioned to a low-power state, or it is de-energized to eliminate the power draw. Both forms can be executed either manually or automatically. *Low-power state* is between a de-energized state and a ready-to-use state. This includes standby, sleep, and hibernate modes, as well any off state that has a parasitic power draw. *De-energize* refers to the state when electricity is not being provided to the device. This is analogous to physically unplugging a device’s power cord from a standard electrical outlet.

All control strategies should provide manual override to accommodate atypical MELs uses (e.g., using a MEL outside normal business hours). Each control strategy must also be evaluated relative to the MEL to be controlled, to ensure a good fit. This evaluation should include an examination of the control strategy's parasitic load versus the MEL parasitic load, as well as the costs of the control versus the energy cost savings.

The following sections discuss different methods to achieve a low-power or de-energized state.

2.2.1.1 Built-in Automatic Low-Power State

The first, and in some cases, most effective, control method is implementing built-in automatic low-power state functionality such as standby or sleep modes. Some MELs manufacturers include this functionality to reduce energy consumption of idle devices. Internal processes monitor idle time, and when the device has been in an idle state for a given period it will be powered down to a low-power state.

Built-in automatic low-power state functionality can be one of the most cost-effective control strategies because it is integral to the MEL and does not require purchasing additional control devices. Several issues may be associated with built-in low-power states, though:

- Computers, for example, can be configured in many ways after they leave the manufacturers. These configurations can cause the low-power states to become inactive so the control method is no longer effective.
- The power draw in a low-power state may be only slightly lower than the ready-to-use state. In this case, the functionality is working as intended, but the drop in power is less than desired or required by the user.
- A device may need to be activated or accessed remotely. If it cannot be accessed remotely in a low-power state, the control method will not meet the user's needs.
- The time it takes to transition from a low-power state to a ready-to-use state can be a concern. If a significant amount of time is required to reach a ready-to-use state, the control may not meet the user's needs.

2.2.1.2 Scheduling Control Device

Certain MELs have predictable load profiles. These devices are used during the same time periods each day and/or at regular intervals. When a MEL has a predictable use schedule, and can be placed into a low-power state or de-energized without issue, a scheduling control device can manage it effectively. This control device applies user programmed schedules to energize and de-energize the MEL to match its use pattern. Scheduling can be used to account for the time it takes for a MEL to become usable by initiating any startup procedures in advance so the MEL is operational when needed.

A scheduling control device can take multiple forms; for example:

- Basic electrical outlet timers that control a single outlet or power strips with integrated outlet timers to control multiple outlets provide local scheduling control. Users program schedules that dictate when an outlet, or outlets, should be energized or de-energized. Some MELs have built-in auto-scheduling that can be used instead of an external scheduling control device. Auto-scheduling refers to a built-in, automatic functionality that will allow a device to transition from a low-power state to a ready-to-use state on a set schedule.
- Scheduling control can be performed from devices in a centralized location. These are typically wireless, plug-and-play devices that control a single or multiple outlets and

communicate with a centralized controller that energizes and de-energizes the outlets based on user programmed schedules. A possible option for implementing centralized scheduling control is through the BMS, which could be programmed to implement schedules to energize and de-energize outlets. Depending on the building's electrical system and control level, schedules could be established for each outlet, or groups of outlets with similar use patterns could be grouped and controlled by a common schedule.

Scheduling devices are generally straightforward, consistent, and reliable. They target the energy that is wasted during nonbusiness hours, but do not necessarily provide the greatest energy savings. For instance, there may be times during business hours when the MEL is not needed and energy is being wasted by having the MEL energized while not in use. All scheduling controls should allow for manual override for the times when energy is needed outside the preset schedules.

A table of commercially available scheduling control devices is provided in Appendix A. This is a sample list only and does not constitute an endorsement of any kind.

2.2.1.3 Load-Sensing Control Device

MELs may have a primary-secondary relationship. A primary device's operation is independent of other (secondary) devices. For example, a computer is a primary device. A secondary device depends on the operation of other (primary) devices. For example, computer monitors and peripherals are secondary devices to a computer. A load-sensing control device should be implemented for such a relationship. It automatically energizes and de-energizes electrical outlets based on the power load of the attached devices. The load-sensing is performed on an electrical outlet or an auxiliary port (e.g., universal serial bus [USB] in the case of a computer).

Load-sensing control has the potential to offer greater energy savings than scheduling control because it can reduce the energy use during business hours and nonbusiness hours. Its drawback is that it depends on "good" operation of the primary (sensed) device. The "good" operation comes from users actively controlling the primary MEL and forcing a low-power state when the device is not in use. Alternatively, built-in functionality in the primary device must be working effectively to automatically put devices into low-power states. If the primary device does not transition to a low-power state, the control method does not save energy.

A load-sensing device can take several forms; for example:

- The most common load-sensing control devices are power strips that sense the load of a primary device and control several secondary devices locally.
- Load-sensing control can also be controlled centrally. Similar to centralized scheduling control devices, these are typically wireless, plug-and-play devices that control a single or multiple outlets. They communicate with a centralized controller that energizes and de-energizes the outlets based on user programmed load thresholds. A benefit to this approach is that the primary and secondary devices can be in different parts of a building. Also, with software-based load sensing and control, the MELs can be programmed such that when the primary device transitions between states, the secondary device can be either energized or de-energized. Again, like the scheduling control, the central control can be provided by a dedicated MELs control system or integrated into the BMS.

A table of commercially available load-sensing control devices is provided in Appendix B. This is a sample list only and does not constitute an endorsement of any kind.

2.2.1.4 Occupancy Control Device

An occupancy control device automatically energizes or de-energizes the MEL based on occupancy. This is appropriate for MELs that need to be functional only when users are present.

In theory, occupancy control has a high potential for energy savings. The control method will energize MELs only when users are present and de-energize them when the space is vacant. This approach gets at the main source of wasted energy during nonbusiness hours and reduces wasted energy during business hours.

Occupancy control does have its drawbacks. It is prone to energizing and de-energizing outlets at inappropriate times. The occupancy sensors need to be focused on the immediate zone surrounding the MEL to be controlled, but not extend into other areas. The MEL should be energized only when a user is in close proximity. The parasitic load of the control device can also be an issue. The currently available occupancy control power strips have significant parasitic loads that reduce the net energy saved by de-energizing MELs.

A table of commercially available occupancy control devices is provided in Appendix C. This is a sample list only and does not constitute an endorsement of any kind.

2.2.1.5 Manual On, Vacancy Off Control Device

A manual on, vacancy off control device is a slight modification of the occupancy control device. Currently, control devices that use manual on, vacancy off are not available. The term refers to a control device that energizes a MEL when it receives manual input from a user, and de-energizes the MEL automatically based on the lack of occupancy of a space. This control should be implemented for MELs that are needed only when users are present.

This approach also has a high potential for energy savings, even more so than a typical occupancy control. The MELs will stay in a de-energized state until a user manually energizes the device. This method requires users to make a conscious decision to energize MELs. This eliminates the wasted energy that is associated with false positives in the occupancy control. The occupancy sensor may have a significant parasitic load. This strategy is commonly implemented in lighting controls because of its effectiveness in reducing wasted energy.

2.2.1.6 Manual Control

Most MELs can be manually powered down. Depending on the equipment, a built-in switch may provide a quick and easy manual method of powering the device down or up. Other devices may have a shutdown procedure that users must perform to manually shut down the device. For some devices, manual control is the best or only method. This refers to controlling the equipment by using built-in power buttons, shutdown procedures, or a control device that energizes and de-energizes electrical outlets based only on manual input.

The effectiveness of manual control depends entirely on user behavior, and should be implemented only if all other methods do not apply. MELs could remain powered up at all times if users do not actively use manual control. When manual control is the only option, all users must be made aware that they are responsible for the operation and energy use of the equipment. They need to be educated about proper use and how much energy can be saved or wasted based on their behavior.

A table of commercially available manual control devices is provided in Appendix D. This is a sample list only and does not constitute an endorsement of any kind.

2.2.2 Selecting a Control Strategy for Miscellaneous Electrical Loads

We developed a flowchart to guide building owners, occupants, operators, and designers to an effective control strategy for a given MEL and its operation. A poster version of the full chart is available for download at www.nrel.gov/buildings/pdfs/mels_controls_flowchart.pdf.

To achieve the greatest energy savings possible, every MEL should first be specified and procured according to the steps outlined in Section 2.1. Once a piece of equipment is specified, the flowchart shown in Figure 2–1 through Figure 2–4 should be used to determine an effective control strategy.

The flowchart guides readers, or MELs champions, through a series of questions that help determine the functionality and use of the MEL under consideration. Depending on the MEL, the flowchart will provide guidance on an effective control strategy; it also provides insights to the weaknesses of the selected MEL if a control is not available. It indicates when the equipment or process should be changed for a more efficient approach. In the cases where control is not available, readers can then turn to equipment manufacturers to determine whether other equipment options better meet their needs, or if the manufacturers should incorporate improvements into their products.

The chart begins by recommending the steps outlined in Section 2.1. The greatest energy savings can be achieved when a MEL has been specified by these steps, and then evaluated and controlled by the strategy recommended in the chart. The chart is also applicable to existing equipment (not specified using the method in Section 2.1) that the users intend to control; the energy savings may not be as great in this case.

With the MEL determined, the chart recommends user education and awareness (see Section 2.1.9). User awareness is key to MELs control. Users tend to leave equipment powered for convenience. Education provides users with the knowledge on how to strike a balance between convenience and energy savings.

In the flowchart, the first MEL feature that is examined is built-in, automatic low-power functionality. The path to a control strategy will depend on whether the MEL has a low-power state, such as standby, sleep, and hibernate. When a low-power state is available, the chart guides readers through a series of questions to determine how the MEL is used. It determines whether the equipment is a primary or a secondary device, whether the equipment needs to be accessed remotely, and whether there are concerns about the startup or warm-up time from a low-power state. It then evaluates the effectiveness of the low-power state and whether options are available to improve it. After navigating through the low-power state branch, the reader will arrive at one of three options:

- A control strategy is recommended.
- No control is available.
- The MEL can be changed and the evaluation restarts at the beginning with the new equipment.

When the MEL does not feature a low-power state, the flowchart proceeds to question whether it can be de-energized and reenergized without issue. Many MELs can be de-energized and reenergized and reach a ready-to-use state instantaneously or with brief delay (e.g., a light bulb). Others may require proper shutdown or startup procedures that prohibit them from being de-energized. Based on the ability to be de-energized, the chart guides the reader through additional questions to evaluate the MEL and to determine a recommended control strategy. Similar to the low-power state branch, navigating through the second main branch determines one of three outcomes:

- A recommended control strategy
- No control available
- Change the equipment and start over.

In general, the chart is organized so each progression to the right moves the MEL toward an appropriate control strategy. When the questions move the reader in a downward direction, the MEL is moving toward no control or a recommendation to replace the MEL. The chart helps point out cases where equipment manufacturers may be requested to improve their products when the reader arrives at a no control option.

All MELs must be well understood to be effectively controlled, whether through built-in functionality or by third-party hardware or software that improves the performance of built-in functionality. Some do not have built-in control and can be managed by external control solutions. Still others may not be controllable because of their configurations, locations, and use patterns.

A MEL's use pattern also has to be known. Some MELs have predictable and consistent use patterns; others do not. Some need to operate only while users are in the immediate vicinity; others may be operated while users are not present. Some MELs may be activated or accessed remotely; others only locally. There can be startup delays or configuration requirements if MELs are controlled. MELs vary greatly in their use patterns, so no single control strategy will effectively manage all devices. Each type of device requires a tailored control strategy to achieve the highest energy savings.

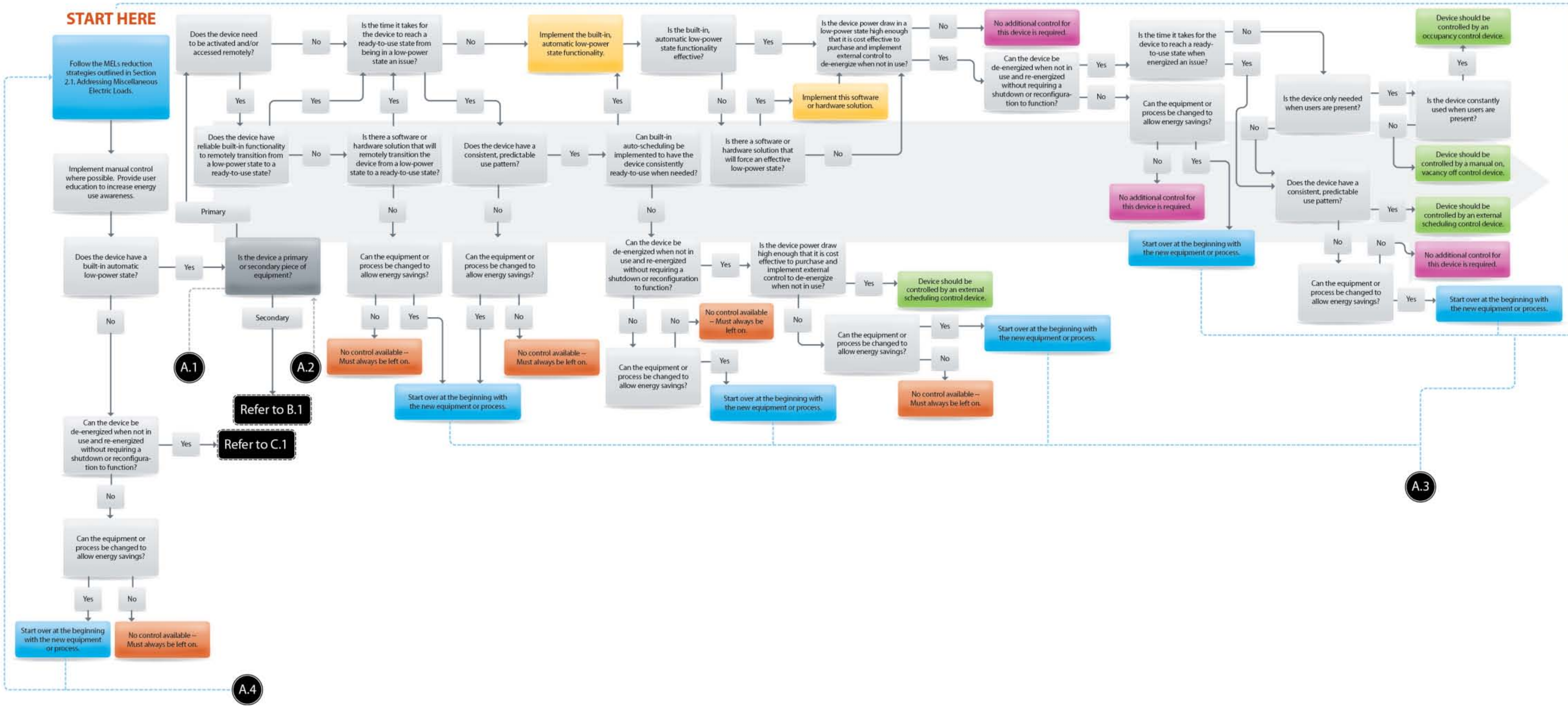

Figure 2–1 MELs control selection process flowchart: Sheet A
(Credit: Joelynn Schroeder`/NREL)

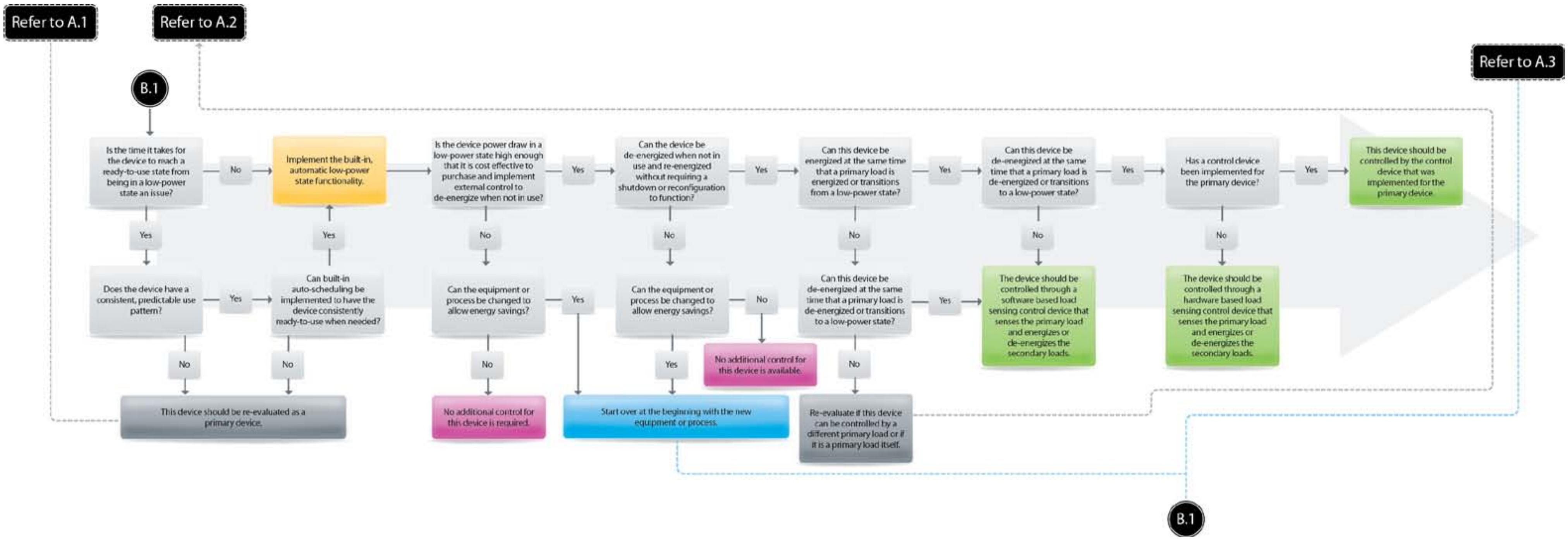

Figure 2–2 MELs control selection process flowchart: Sheet B
(Credit: Joelynn Schroeder`/NREL)

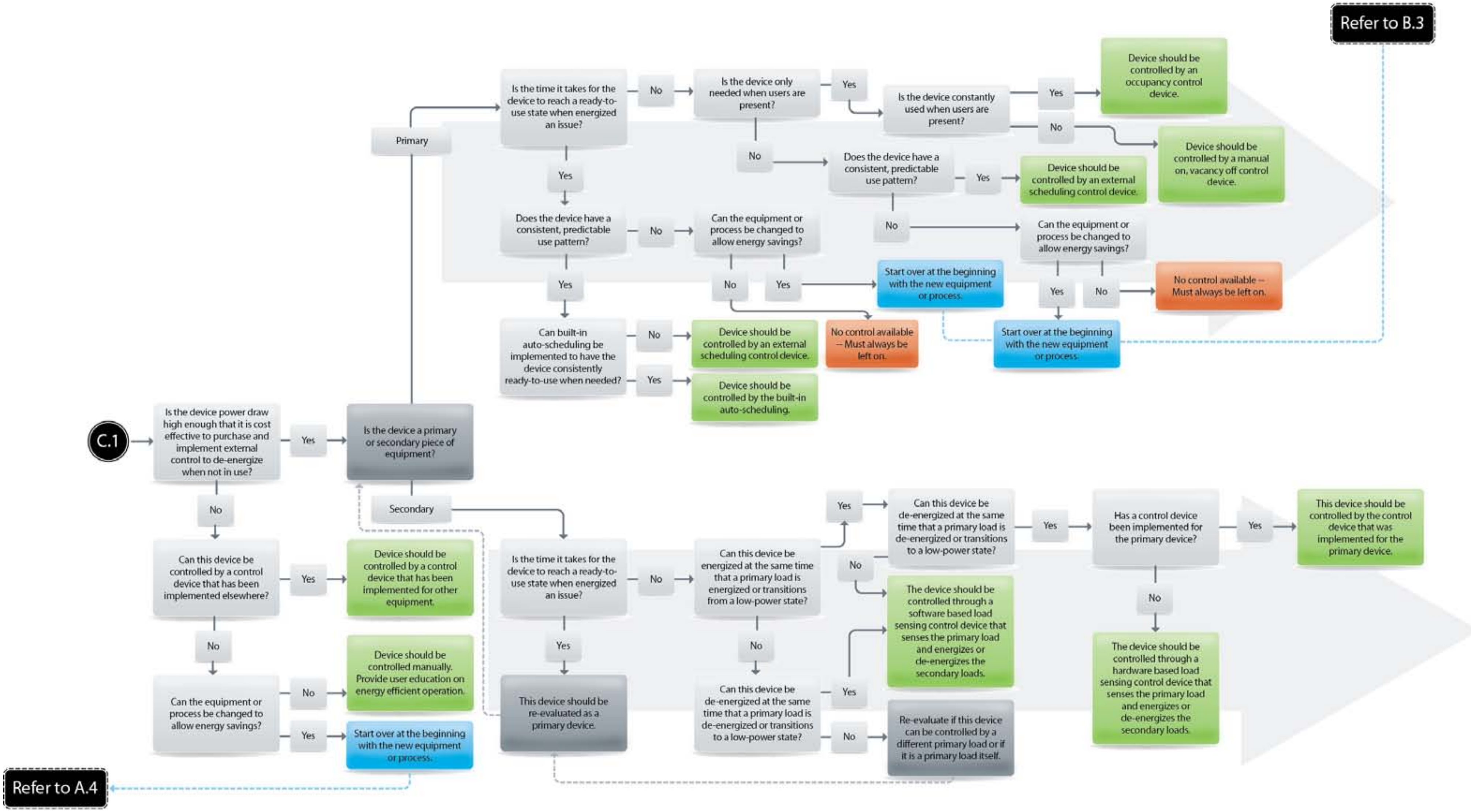

Figure 2–3 MELs control selection process flowchart: Sheet C
(Credit: Joelynn Schroeder`/NREL)

MELs Control Selection Process

Legend	
Auto-Scheduling	Refers to built-in automatic functionality that will allow a device to transition between power states based on set schedules to account for the time it takes to become usable.
De-energized	Refers to the state when electricity is not being supplied to the device. This is analogous to the state when the device power cord is physically unplugged from a standard electrical outlet.
Energized	Refers to the state when electricity is being supplied to the device. This is analogous to the state when the device power cord is physically plugged into a standard electrical outlet.
External Scheduling Control Device	Refers to a control device that automatically energizes and de-energizes electrical outlets based on user defined schedules.
Load Sensing Control Device – Hardware Based	Refers to a control device that automatically energizes and de-energizes electrical outlets based on the power load of the attached devices. The load sensing is performed on an electrical outlet or an auxiliary port (USB in the case of a computer). This is done locally with hardware (e.g. MELs Control Power Strips) to analyze the load.
Load Sensing Control Device – Software Based	Refers to a control device that automatically energizes and de-energizes electrical outlets based on the power load of the attached devices. The load sensing is performed on an electrical outlet or an auxiliary port (USB in the case of a computer). This is done centrally with computer software to analyze the load.
Low Power State	Refers to a power state that is between a de-energized state (or any other true zero power draw states) and a ready-to-use state. This state includes standby, sleep, or hibernate modes, as well as any off state that has a parasitic power draw.
Mutual On, Vacancy Off Control Device	Refers to a control device that energizes electrical outlets only on manual input and automatically de-energizes electrical outlets based on vacancy of a space.
Manual Control	Refers to controlling the equipment by using built-in power buttons, shutdown procedures, or, through the use of a control device that energizes and de-energizes electrical outlets based on manual input only.
Occupancy Control Device	Refers to a control device that automatically energizes or de-energizes electrical outlets based on occupancy.
Primary Device	Refers to a device whose operation is independent of the operation of other (secondary) devices. A computer is an example of a primary device.
Secondary Device	Refers to a device whose operation is dependent on the operation of other (primary) devices. A computer monitor, or other peripherals, are examples of secondary devices.
	Designates the implementation of built-in functionality for the device in question.
	Designates the recommended control strategy for the device in question.
	Designates when additional control for the device in question is not needed.
	Designates when a control strategy is not available for the device in question.
	Designates a change in equipment or process that requires a complete re-evaluation from the beginning of the flow chart.
	Designates re-evaluating a secondary device as a primary device.

NOTE: All control strategies must allow manual override or bypass of the control.

Figure 2–4 MELs control selection process flowchart: legend
(Credit: Joelynn Schroeder`/NREL)

2.2.2.1 Walkthrough of Control Strategy Flowchart for a Computer

This example will illustrate the process a reader would follow to determine the recommended control strategy for a computer. The reader follows the steps outlined in Section 2.1 to determine that this particular computer will meet the user's needs. To determine a suitable control strategy, he or she must then turn to the flowchart. The first step is to educate the computer user on energy use and what he or she can do to help reduce it.

The reader reaches the first question (see Figure 2–5). In this example, the computer can transition to a standby state.

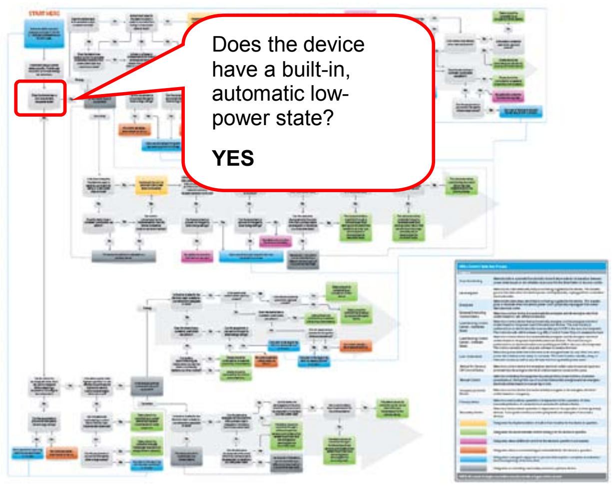

Figure 2–5 Flowchart control strategy for a computer example: question 1
(Credit: Joelynn Schroeder`/NREL)

The process moves to the next question (see Figure 2–6). The computer is a primary device because its operation does not depend on the operation of other equipment in the area.

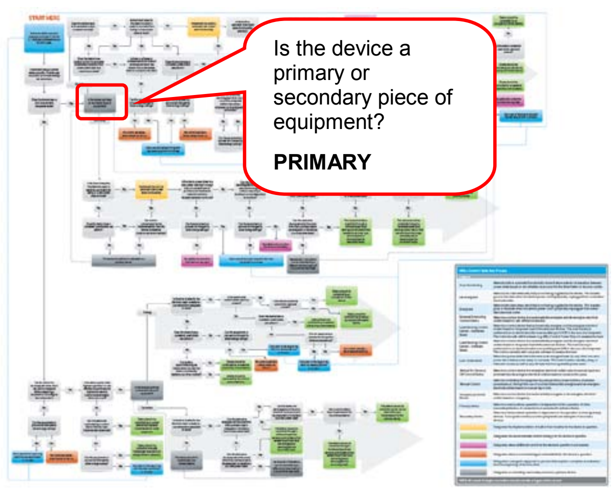

Figure 2–6 Flowchart control strategy for a computer example: question 2
(Credit: Joelynn Schroeder`/NREL)

The next question is whether the computer needs to be accessed remotely (see Figure 2–7). This particular computer does not need to be accessed remotely, so the process continues to move toward a recommended control strategy.

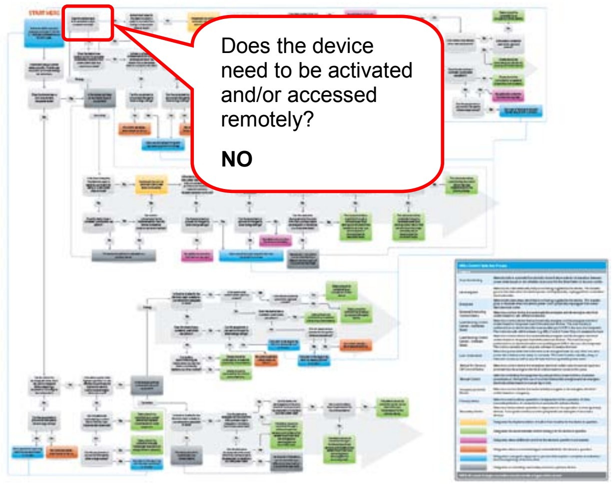

Figure 2–7 Flowchart control strategy for a computer example: question 3
(Credit: Joelynn Schroeder`/NREL)

The reader must now determine whether the time it takes for the computer to come out of standby is an issue (see Figure 2–8). This computer transitions from standby to a ready-to-use state in very little time, so the reader will proceed to on the chart.

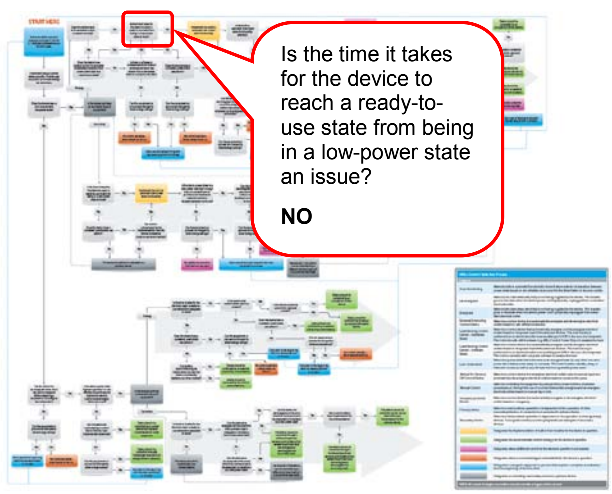

Figure 2–8 Flowchart control strategy for a computer example: question 4
(Credit: Joelynn Schroeder`/NREL)

The chart now recommends that the low-power state (standby in this case) be implemented as the first form of control for the computer (Figure 2–9).

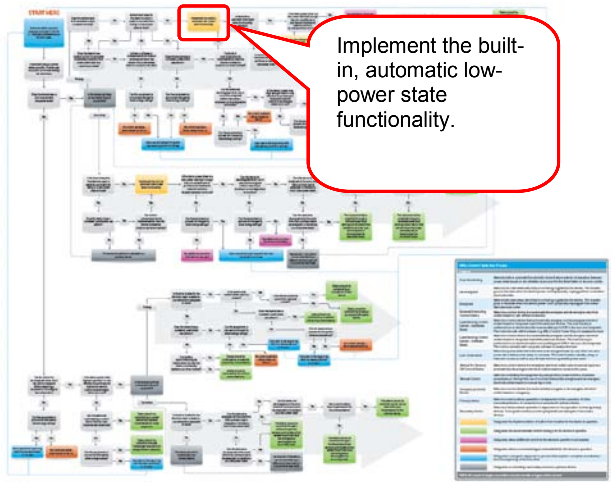

Figure 2–9 Flowchart control strategy for a computer example: low-power state implemented
(Credit: Joelynn Schroeder`/NREL)

The reader must now analyze the effectiveness of the built-in standby function (see Figure 2–10). When the computer is in standby, is there a significant reduction in the power draw compared to its ready-to-use state? For this example, the computer goes into standby consistently and reliably; once in standby, there is a significant power reduction.

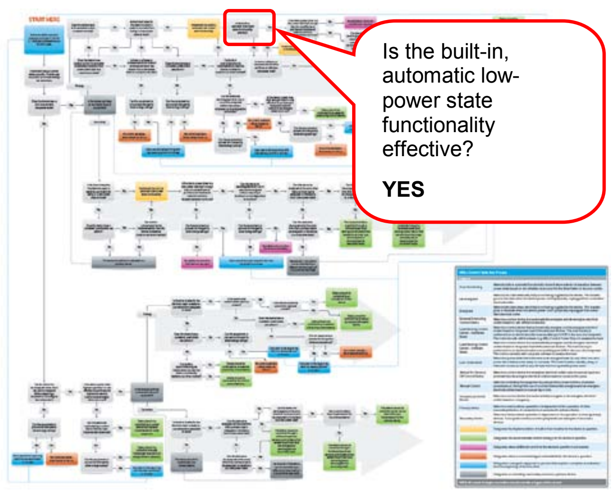

Figure 2–10 Flowchart control strategy for a computer example: question 5
(Credit: Joelynn Schroeder`/NREL)

The reader must perform additional analysis at this point (Figure 2–11). In this case, the computer's parasitic load is greater than that associated with an external control strategy. In addition to the parasitic load analysis, the building's energy goals and economics are such that further controlling the computer is cost effective. (Refer to Section 2.3 for a guide on how to determine whether a MEL is cost effective to control.)

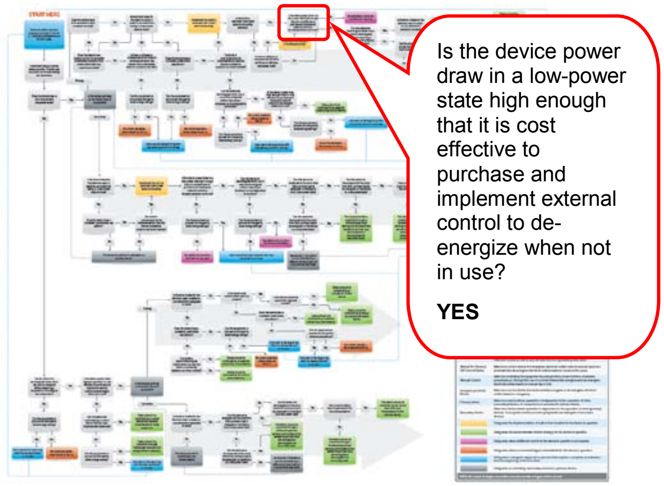

Figure 2–11 Flowchart control strategy for a computer example: question 6
(Credit: Joelynn Schroeder`/NREL)

To further reduce the computer's energy use, it must be de-energized when not in use. The reader must determine whether it can be de-energized and reenergized without being reconfigured (Figure 2–12). This computer cannot be de-energized.

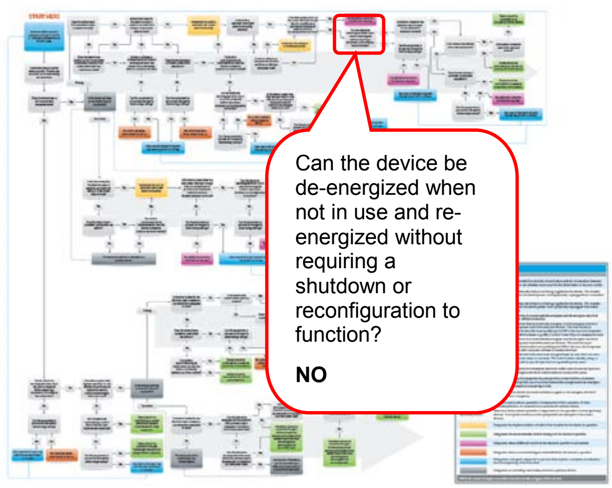

Figure 2–12 Flowchart control strategy for a computer example: question 7
(Credit: Joelynn Schroeder`/NREL)

The chart guides the reader to the next question (see Figure 2–13). The computer is energy-efficient and must be used to meet the user's needs. It cannot be changed out for a different piece of equipment.

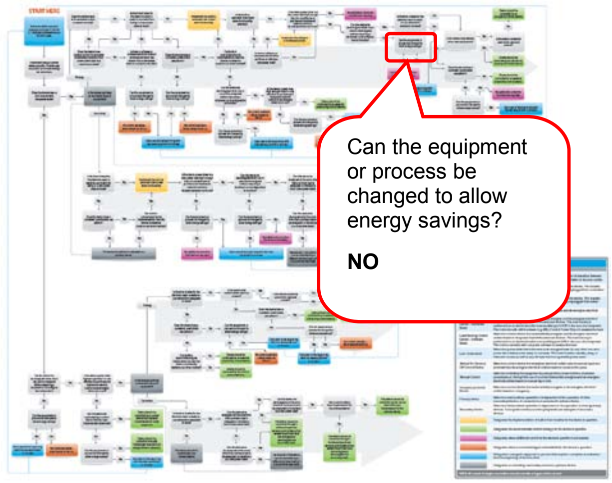

Figure 2–13 Flowchart control strategy for a computer example: question 8
(Credit: Joelynn Schroeder`/NREL)

This takes the reader to a recommended control strategy (Figure 2–14). No additional control is required. The computer is recommended to be controlled by its built-in low-power state and manual shutdown procedures. If an external control device was recommended, extensive lists of devices are provided in Appendix A through Appendix D.

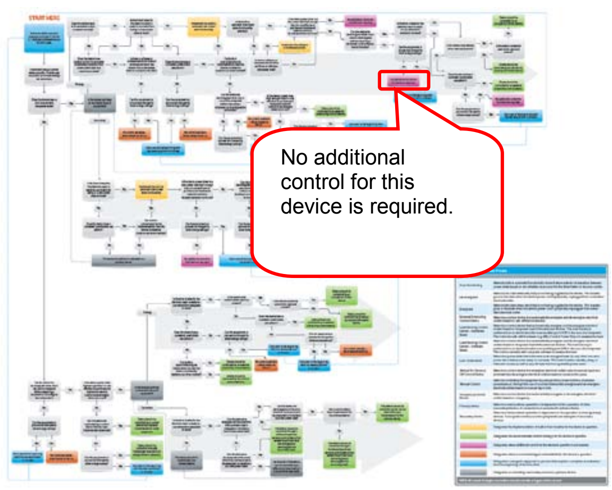

Figure 2–14 Flowchart control strategy for a computer example: recommended control
(Credit: Joelynn Schroeder`/NREL)

2.2.2.2 Walkthrough of Control Strategy Flowchart for an Ice Machine

This example will illustrate the process a reader would follow to determine the recommended control strategy for an ice machine. The reader follows the steps outlined in Section 2.1 to determine that an ice machine will meet the user's needs. To determine a suitable control strategy, the reader must then turn to the flowchart. The first step is to educate the ice machine user to understand its energy use and what he or she can do to help reduce it.

On the chart, the reader starts with the first question (see Figure 2–15). In this example, the ice machine cannot transition to a standby state.

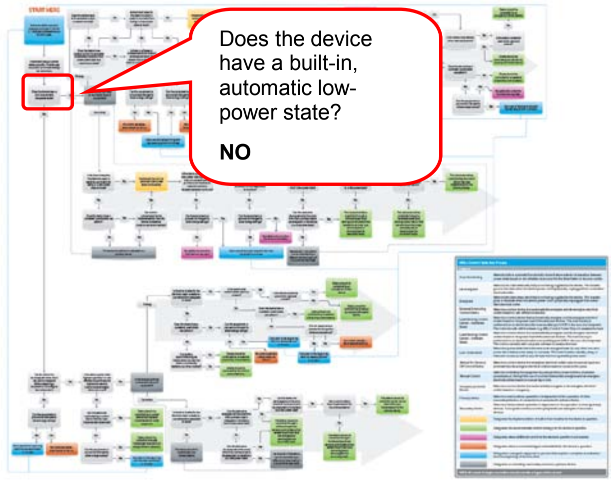

Figure 2–15 Flowchart control strategy for an ice machine example: question 1
(Credit: Joelynn Schroeder`/NREL)

The process moves to the next question (see Figure 2–16). The ice machine can be de-energized without being reconfigured.

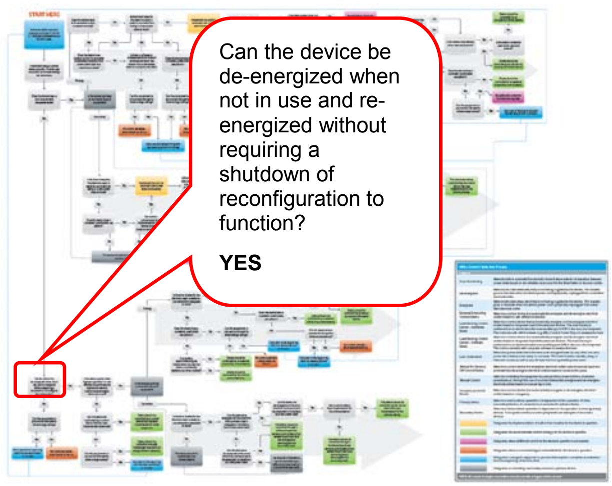

Figure 2–16 Flowchart control strategy for an ice machine example: question 2
(Credit: Joelynn Schroeder`/NREL)

The next question is whether the ice machine's power draw is high enough that purchasing and implementing external control is cost effective (see Figure 2–17). The ice machine has a significant load when it is operating, whether or not it is needed, so the process continues to move to the right on the flowchart. (Refer to Section 2.3 for a guide on how to determine whether a MEL is cost effective to control.)

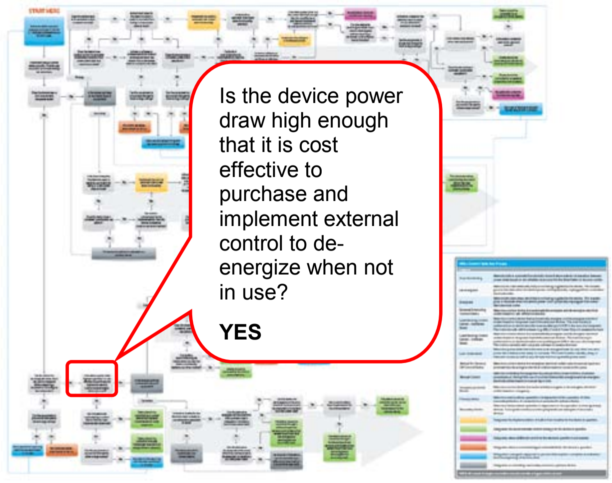

Figure 2–17 Flowchart control strategy for an ice machine example: question 3
(Credit: Joelynn Schroeder`/NREL)

The reader must now determine whether the ice machine is a primary or a secondary piece of equipment (see Figure 2–18). The ice machine is a primary device because its operation does not depend on the operation of other devices, so the reader will proceed on the chart.

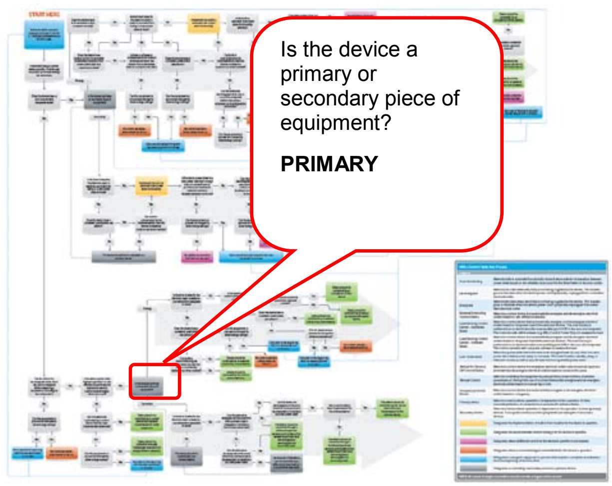

Figure 2–18 Flowchart control strategy for an ice machine example: question 4
(Credit: Joelynn Schroeder`/NREL)

The reader must now determine whether the time it takes for the ice machine to reach a ready-to-use state from being de-energized and reenergized is an issue (see Figure 2–19). The ice machine requires a significant amount of time to produce ice after being de-energized and reenergized, so the reader will proceed down on the chart.

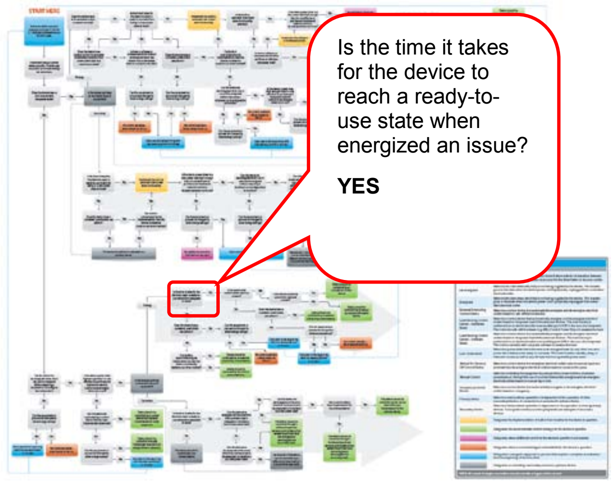

Figure 2–19 Flowchart control strategy for an ice machine example: question 5
(Credit: Joelynn Schroeder`/NREL)

The reader must now analyze the usage pattern of the ice machine to see if it is predictable and consistent (see Figure 2–20). The ice machine has a predictable use pattern, as it needs to provide ice from 7:00 a.m. to 5:00 p.m. The reader will proceed on the chart.

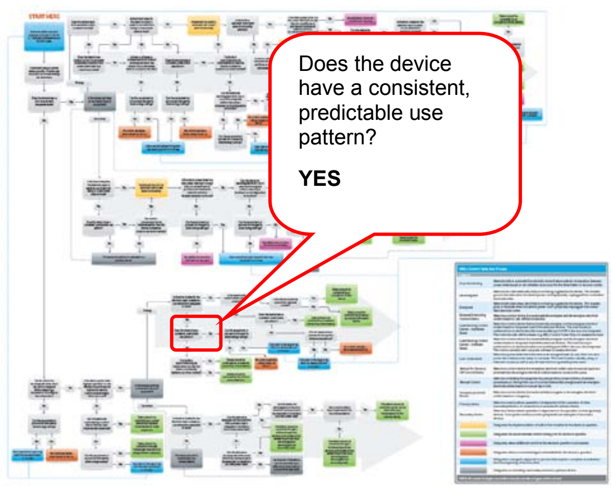

Figure 2–20 Flowchart control strategy for an ice machine example: question 6
(Credit: Joelynn Schroeder`/NREL)

The reader must now determine whether built-in auto-scheduling can be implemented to have the ice machine consistently ready to use (see Figure 2–21). The ice machine does not have auto-scheduling, so it should be controlled by an electrical outlet timer.

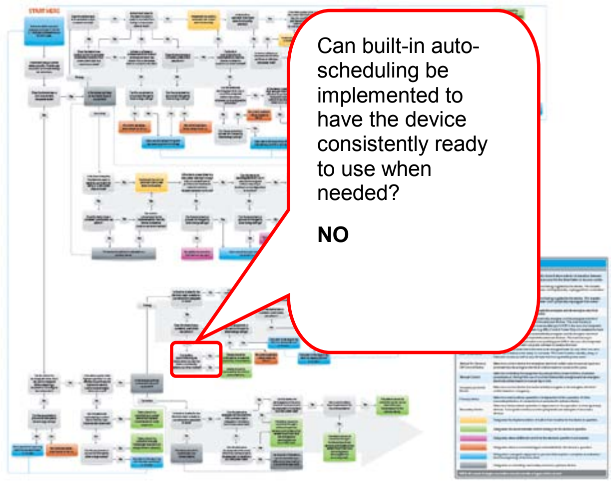

Figure 2–21 Flowchart control strategy for an ice machine example: question 7
(Credit: Joelynn Schroeder`/NREL)

This takes the reader to a recommended control strategy (Figure 2–22). An electrical outlet timer should be used to energize the ice machine a few hours before it is needed (7:00 a.m.) so sufficient ice is ready. The electrical outlet timer should de-energize the ice machine at 5:00 p.m. each day to mitigate wasted energy. Appendix A provides an extensive list of scheduling control devices.

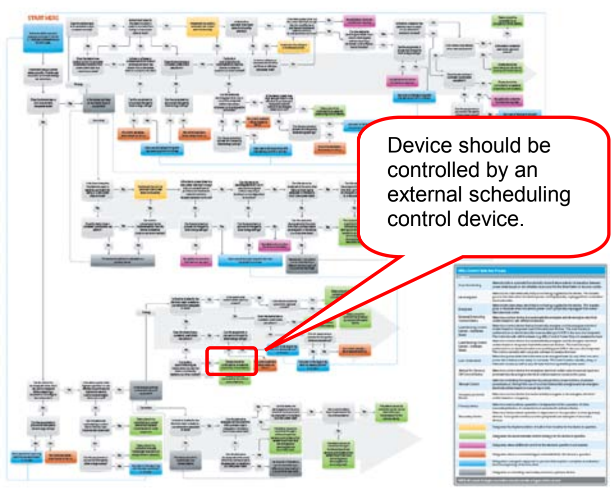

Figure 2–22 Flowchart control strategy for an ice machine example: recommended control
(Credit: Joelynn Schroeder`/NREL)

Section 2.2.3 provides the results of the flowchart analysis for typical MELs.

2.2.3 Controlling Typical Miscellaneous Electrical Loads

NREL researchers have performed extensive MELs research through work on the RSF project and on Commercial Building Partnership projects. Table 2–2 shows the recommend control strategies for MELs that are typically found in commercial buildings. The devices listed have been processed by the flowchart shown in Section 2.2.2 to arrive at the recommended strategies.

Table 2–2 Recommended Controls for Typical MELs

Device	Built-In Automatic Low-Power State	Scheduling	Load Sensing	Occupancy	Manual On, Vacancy Off	Manual Control	No Control
Audio equipment		X	X	X	X		
Battery chargers		X					
Cash registers		X		X	X		
Computer monitors	X		X				
Credit card machines	X		X				
Decorative lighting			X		X		
Desktop computers	X						
Digital photo frames			X		X		
Dishwashers		X					
Drinking fountains		X		X	X		
Electric hole punchers		X	X		X		
Electric information displays	X	X		X	X		
Electric pencil sharpeners		X	X		X		
Electric staplers		X	X		X		
Fans		X		X	X		
Floor cleaners		X			X	X	
Floor polishers		X			X	X	
Freezers							X
Gym equipment		X			X		
Heaters		X			X		
Label makers/printers		X	X		X		
Laptop computers	X		X				
Ovens/stoves/ranges		X					
Paper shredders		X	X		X		
Peripherals			X				
Personal print/copy equipment			X				
Phones	X						X
Projectors	X	X	X		X		
Refrigerators							X
Shared print/copy equipment	X	X					
Small kitchen appliances		X			X		
Smart boards		X			X		
Task lighting			X		X		
Televisions	X	X		X	X		
UPS units		X	X				
Vacuums					X	X	
Vending machine – nonrefrigerated		X		X			
Vending machine – refrigerated		X					X
Water coolers		X		X	X		
Water filters		X		X	X		
Water heaters		X		X	X		

Several MELs have multiple recommended strategies, because MELs and buildings are operated in a variety of ways. Devices that are not listed or items that are listed with multiple recommendations should be analyzed with the flowchart to arrive at the best control strategy for the project and MEL at hand.

2.3 Selecting a Cost-Effective Control Device

The process in the preceding sections will determine a suitable approach to control a MEL, but additional evaluation is required to arrive at a specific control device. For any given strategy, multiple control devices are commercially available that offer similar features. The reader must select one product over another based on the MEL and project under review.

The parasitic load of each potential control device must now be evaluated. The parasitic load of the control device must be low enough that it does not negatively offset the energy saved by controlling the MEL. Ideally, the control device would have zero parasitic load. Testing has shown that the parasitic load of the control device needs to be considered relative to the MELs that it will control. For example, a control device with a load of 3 W may be acceptable for a MEL that has a parasitic load of 20 W, depending on the cost of the device, the cost of electricity, and the desired payback. If the MEL had a parasitic load of 2 W, however, the control device would use more energy than it saves, so it should be changed to one that has a lower parasitic load.

MELs control devices have an associated cost for the additional features over a standard power strip. Once a control strategy is determined for a given MEL, the devices that feature that control must be evaluated to determine whether they function as intended and the additional cost is justified.

The price of MELs control devices can vary greatly. At the time this report was written, simple scheduling devices could be purchased for less than $20; strategies tied to the BMS may be $1000 or more per point. Thus, the cost of the wasted energy should be compared to the cost of the control device. The business case that was developed in Section 2.1.3 can be used to determine whether the applicable control device costs can be justified and if the project payback requirements are met.

Figure 2–23 shows the minimum average power draw for a MEL that can be cost-effectively controlled by a control device. The graph was developed assuming 9 hours of operation per workday and 250 workdays per year. It is also based on a 2-year payback period and for simplicity does not account for demand charges. (See Appendix E other payback periods.) For a given utility rate, all MELs with an average power above the line should be controlled. If a MEL's power is below the line, controlling it is not cost effective. For example, if the utility rate is $0.06/kWh, and a control device is available for $30 per device, it is cost effective to control all MELs with an average power of 38 W or more.

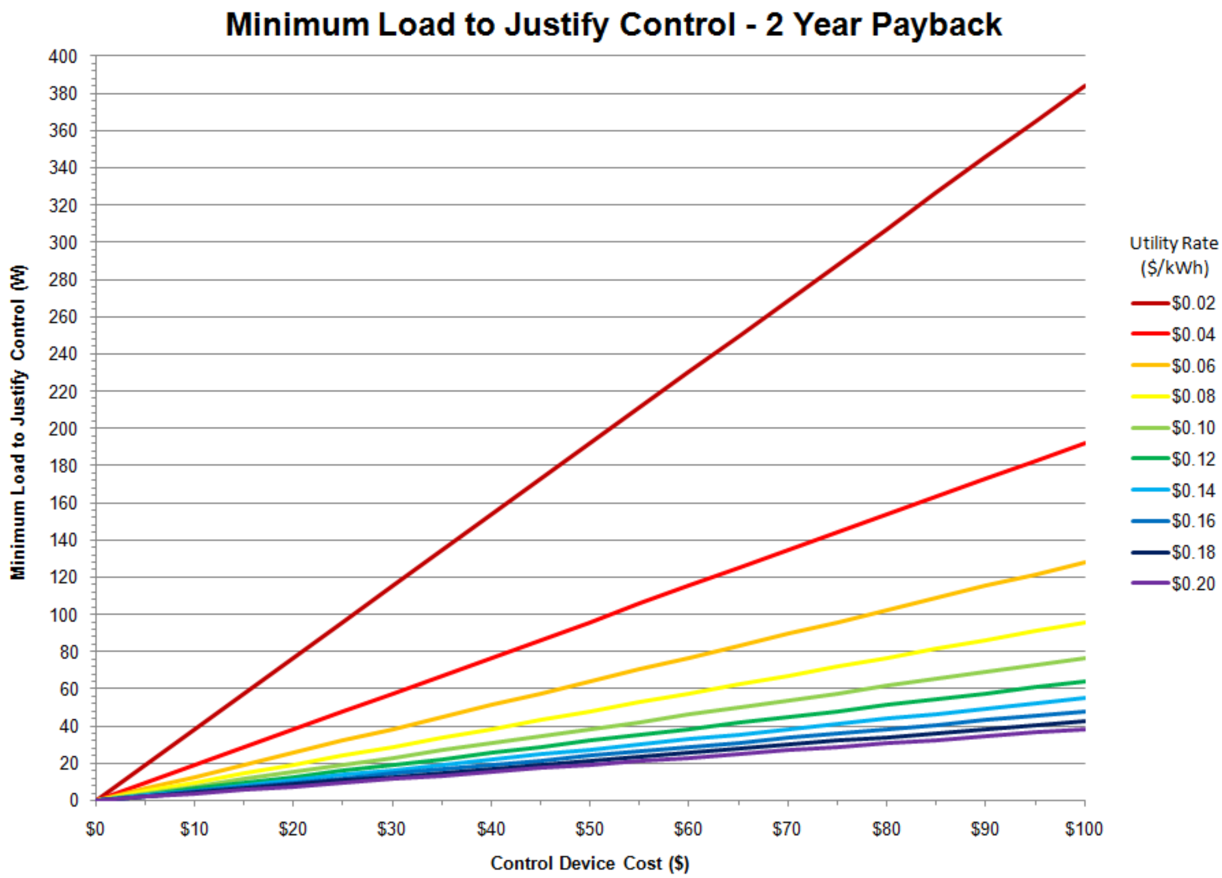

Figure 2–23 Minimum load that can be cost effectively controlled by a control device
(Credit: Chad Lobato/NREL)

2.3.1 Other Evaluation Criteria for Control Device

In addition to the effectiveness in reducing MELs, control devices should also be evaluated on usability, form factor, and aesthetics. Perhaps most importantly, they should be user friendly. When control devices become complicated, the users will bypass the control and complexity. The control devices should also incorporate a manual override. There will be times that fall outside typical use patterns when the MEL will be needed but will be de-energized. The manual override will enable the user to energize the MEL when needed. It can also promote "good behavior" by enabling the user to manually de-energize equipment when not in use.

The devices should integrate well with the MELs they are to control and with the building space. They should be sized to fit into the spaces between the MEL and the electrical outlet. If the device is intended to be visible, its design should, if possible, integrate well with the building decor and furniture.

Energy metering capabilities can add value to control devices. The metering is not critical for control, but it does provide feedback. When metered data are paired with user education, users can take action and alter their behavior to reduce energy use. The metering can indicate when energy is being wasted. It will highlight times when energy was used unexpectedly and the situation can be investigated to determine the reason for the wasted energy. To take full advantage of metering, the measured data for all MELs in a building should be available to all building occupants. They would then be able compare their energy use to their peers and possibly compete to reduce energy use. Desirable features of a control device with metering are provided in Section 2.1.2.1.

Table 2–3 illustrates the evaluation criteria used to select a control device.

Table 2–3 MELs Control Evaluation Criteria

Parasitic Load Mitigation	Power Management	Usability, Form Factor, and Aesthetics	Metering Capability	Price
• Minimal parasitic load for the control device • Minimize or eliminate the parasitic load of the MELs	• Consistent and reliable operation of the controlled MEL • Number of controlled outlets on the control device meets occupants needs	• User friendly • Incorporated manual override • Physical dimensions do not cause space issues • Integrates well with the workstation • Integrate well with building decor and furniture • Ability for the electrical outlets to be oriented to accommodate different sized plugs	• High level of accuracy with the ability to be recalibrated • Local display to provide user feedback • Ability to record and store electrical load time series data	• Energy savings from the control device justifies higher cost and the payback requirements are met

3.0 Potential Equipment Improvements for the Manufacturers

The flowchart in Figure 2–1 through Figure 2–4 sometimes recommends that the MEL be changed or that there is no control. Those situations indicate areas that MEL equipment manufacturers could improve to reduce the energy use of their products.

3.1 Built-in Low-Power Functionality

One of the first checks in the flowchart is whether the equipment has built-in low-power functionality. If it does not, it moves one step closer to a no control or change out recommendation. A move in this direction indicates that the reader needs to work with, or request that, the manufacturers improve their equipment design to include low-power states.

Ideally all MELs would have built-in low-power functionality. It can be difficult to accurately match an external control strategy to a given MEL. If the control was an integrated feature of the MEL, there would be less need to match a control strategy to the use of the equipment. It could reduce costs (to users) by eliminating the need to purchase additional devices. Built-in control would also offer the potential for more consistent and reliable control. The MEL manufacturers would be more qualified to tailor the control to the MEL instead of having to use a third-party control that is less effective and designed to be universally applicable.

3.1.1 Remote Access

Some MELs receive a "no control" recommendation (from the flowchart in Figure 2–1 through Figure 2–4) even though they have built-in low-power functionality, because they cannot be brought out of a low-power state remotely. In this case, the reader would request the manufacturers to improve their equipment by incorporating remote "wake up" functionality. Computers are an example of MELs that have low-power functionality, but are left in idle, uncontrolled, states because they need to be accessed remotely. There is the potential for significant wasted energy if equipment is left powered in idle states for the occasional times when they need to be accessed.

3.1.2 Warm-up Time

Another issue that the reader may request manufacturers to improve is warm-up time. Some MELs can go uncontrolled because it takes too much time for them be "ready to use" from a low-power state. Users will disable built-in low-power functionality if it takes too long for the equipment to become ready to use.

3.1.2.1 Auto-Scheduling

If a given MEL has a low-power state and a predictable use pattern, but a significant warm-up time, it would benefit from a built-in auto-scheduling. This functionality would begin the warm-up process in advance so that it is ready to be used when it is needed. Without this functionality the MEL would go uncontrolled and waste energy.

3.1.3 Effective Low-Power Functionality

At times, MELs will receive a "no control" recommendation (from the flowchart in Figure 2–1 through Figure 2–4) because its low-power functionality is not effective. This should indicate that the reader should request product improvements.

An effective low-power state functions reliably and consistently. The equipment would transition to a low-power state every time it sits idle for a specified time period. Once in a low-power state, the power draw should be designed to be drastically reduced from the idle or in-use power state. Our research has shown that many MELs have inconsistent low-power functionality. Various processes keep the MELs from transitioning to their low-power states. We have also seen that in some cases, the power draw does not decrease enough to be useful.

3.2 De-Energize and Reenergize Functionality

Most control devices reduce MEL energy consumption by de-energizing the outlet that provides energy to the equipment. Energy is restored to the outlet when the MEL needs to be used again. To take advantage of these control devices, MELs must be able to be de-energized and reenergized and be ready to use. Many MELs cannot be controlled because they cannot be de-energized and reenergized. These MELs sometimes require a specific shutdown procedure and may become damaged if they are de-energized before completing the shutdown. Or, they may not be damaged by being de-energized, but instead require a lengthy reconfiguration process once reenergized. Other devices cannot not be de-energized and reenergized because of convenience or safety concerns. They simply take too long to warm up to be ready to be used when energy is restored. When the flowchart is used to evaluate a MEL, and no control is recommended because it cannot be de-energized, it is a sign that the products should be improved to reduce energy use.

4.0 Research Support Facility Results: Miscellaneous Electrical Load Controls Evaluation

With almost 1000 workstations in the RSF, a heavy emphasis was placed on procuring energy-efficient equipment and finding the best strategy to control it to meet the building energy goals. In previously occupied NREL office spaces, the power strips used at workstations were standard multi-plug units with surge protection and manual on/off power switching on the strip. They did not feature automated power control, and did not have measureable parasitic loads.

The following sections highlight the process and results of evaluating various MELs controls in the RSF.

4.1 Evaluating the Effectiveness of Various Miscellaneous Electrical Loads Control Strategies in the Research Support Facility

Commercially available MELs control devices were evaluated for their energy saving effectiveness. Most were tested on workstations with common equipment. Each user at each workstation has a unique usage pattern, which is a function of work schedule, time spent at the workstation, and time spent using the computer. Therefore, results are presented on a user-by-user basis instead of as an average. In the following sections, "good" user behavior is when users power down their workstations each day. Ideally, "good" users would also put their computers into standby and turn off their task lights each time they are away from their workstations.

A few control devices were tested in other areas of the building. The results are presented in the following sections.

4.1.1 Baseline Measurements: No Control

We monitored a set of workstations with uncontrolled plug loads to establish a baseline of energy use profiles. A typical RSF workstation has two light-emitting diode (LED) backlit liquid crystal diode (LCD) monitors (consuming approximately 15 W each), a laptop (consuming approximately 30 W), laptop docking station, and a 6-W LED task light. Some users had additional equipment based on their job responsibilities. The computer power management settings cut signal to the monitors after 5 minutes of idle time; metering indicated that this setting worked automatically and consistently.

The NREL Information Services Office (IS) managed the campus information technologies. IS implemented additional power management settings on all computers that were supposed to force standby after 15 minutes of idle time; however, our baseline measurements showed that these settings did not work. None of the laptops we metered went into standby automatically. Solutions are presented in later sections.

Figure 4–1 represents the "no control" workstation that was used as a basis for comparison when evaluating MELs controls devices. All the equipment (the laptop, docking station, two LED backlit LCD monitors, and an LED task light) was left powered 24/7. All the computer power management settings were disabled so the computer would not go into standby mode or screensaver mode, or cut signal to the monitors. The average load of the "no control" workstation was 62 W.

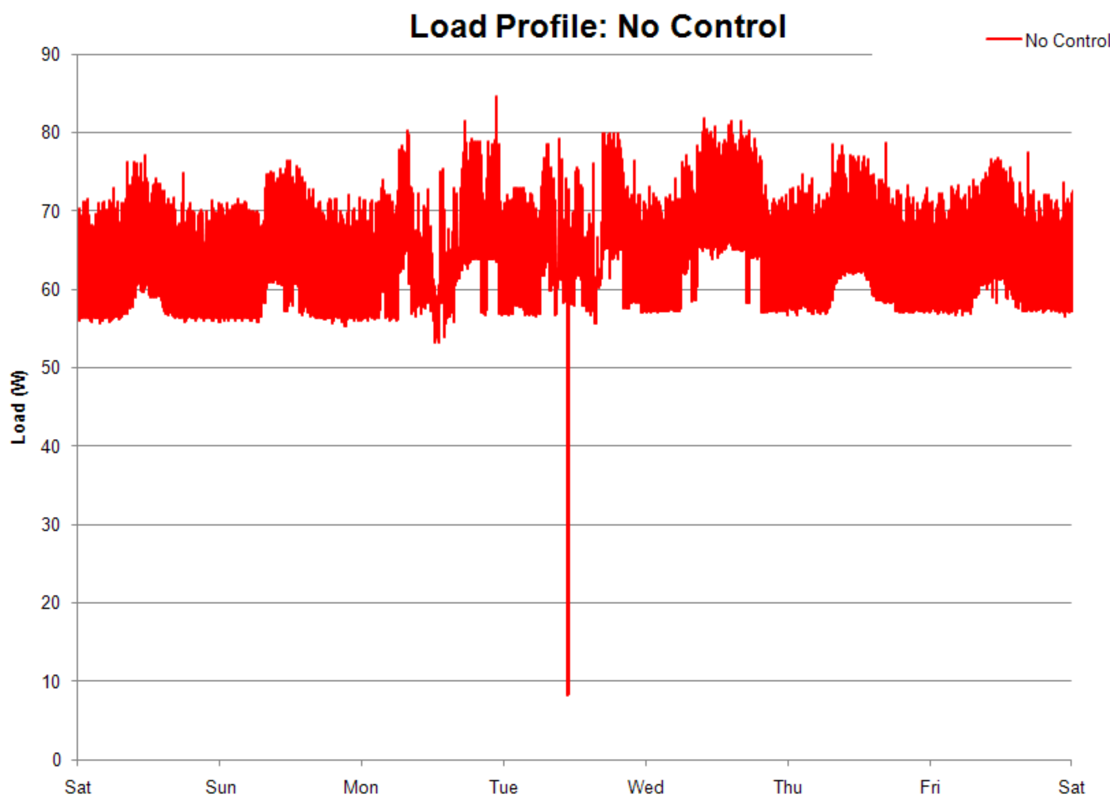

Figure 4–1 Load profile of the "no control" workstation; all equipment powered up 24/7
(Credit: Michael Sheppy/NREL)

4.1.1.1 Energy Impact of User Behavior: The Importance of User Education

Results from the baseline measurements of uncontrolled workstations revealed the importance of encouraging "good" user behavior. Ideally, all MELs control strategies would counteract "bad users," but not all strategies are "user proof." Controlling every MEL is not always feasible, because of budget constraints or because implementing and managing a given strategy is too time consuming. Encouraging "good" user behavior can be an effective and inexpensive control strategy.

Figure 4–2 and Figure 4–3 show the workstation load profiles for a user with good behavior and a typical user, respectively. Both workstations had the following controls implemented:

- No signal to monitors after 5 minutes of idle time
- Monitors with built-in automatic low-power state
- Manual power management control.

Figure 4–2 shows a peak demand that was 8 times higher than that shown in Figure 4–3 (915 W compared to 120 W); this was due to extra equipment, including a large printer and several other miscellaneous electrical items. Despite the high peak demand, this workstation used about half the energy (weekly average load 3.4 kWh compared to 6.2 kWh) because everything was turned off at night. The user depicted in Figure 4–3 was not educated about effective power management and simply locked the computer when away from the workstation and thereby wasted energy. Figure 4–3 illustrates the need for user education and the consistent use of standby functionality.

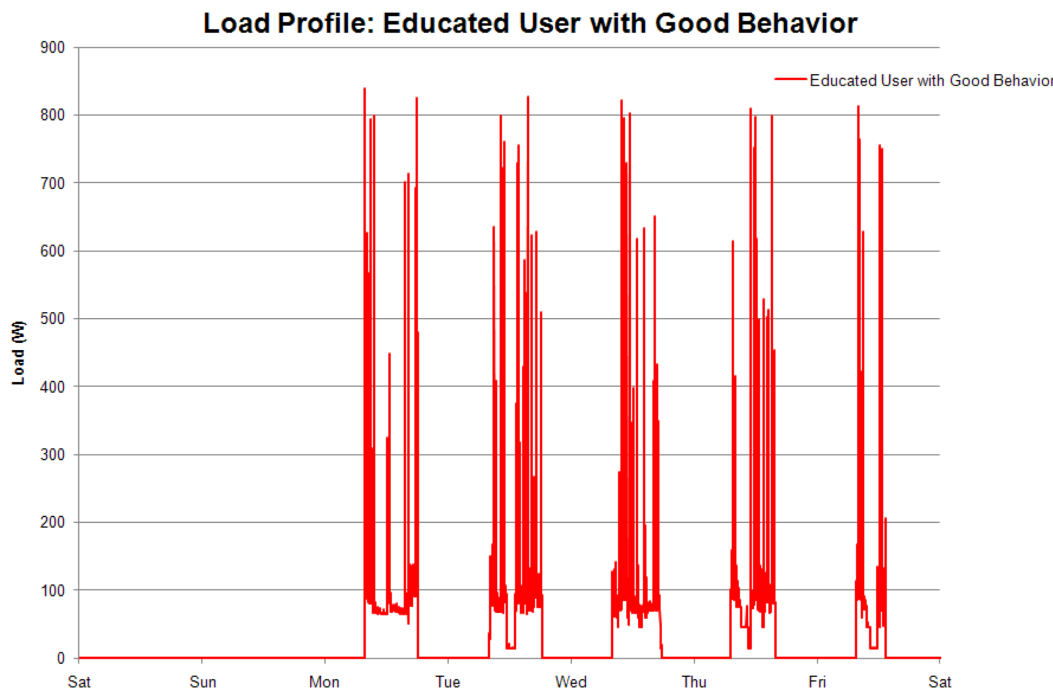

Figure 4–2 Measured load profile of a workstation with good occupant behavior
(Credit: Chad Lobato/NREL)

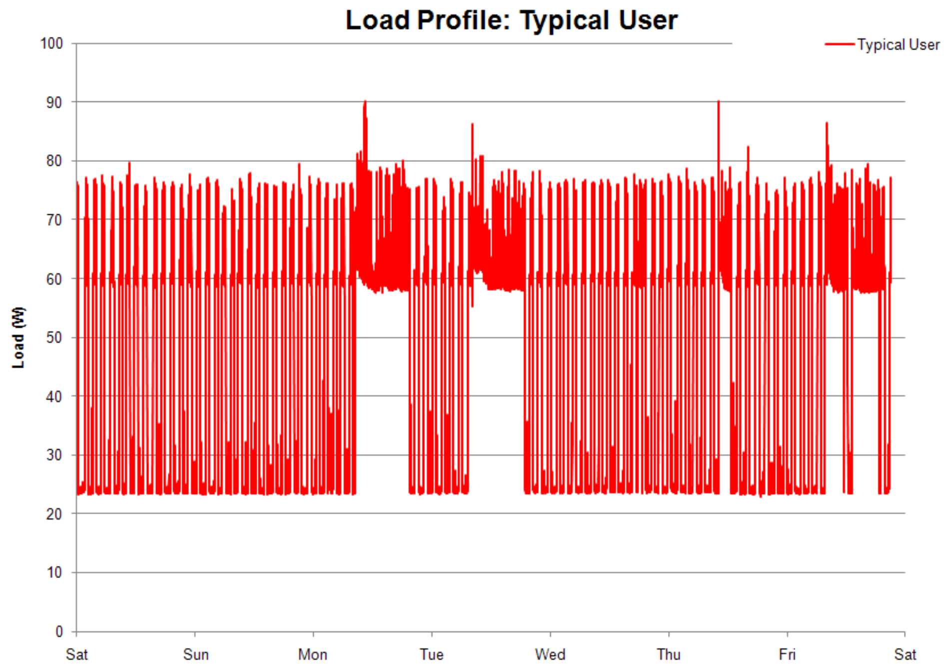

Figure 4–3 Measured load profile of a workstation without good occupant behavior
(Credit: Chad Lobato/NREL)

4.1.2 Built-In Automatic Low-Power State Control

As mentioned in Section 4.1.1, NREL's IS implemented computer power management settings that force standby after 15 minutes of idle time. These efforts were found to be ineffective for NREL because our network activity kept the computers from going into standby. We evaluated several third-party programs (Invent 2011; Slawdog 2003) to counteract the network activity and to consistently and automatically force standby.

Figure 4–4 shows the load profile of a workstation that used an effective third-party power management program. This program was set to force standby after 6 minutes of idle time and after 5:00 p.m. each day. This workstation had the following additional controls implemented: no signal to monitors after 5 minutes of idle time; monitors with built-in automatic low-power state; and manual power management control.

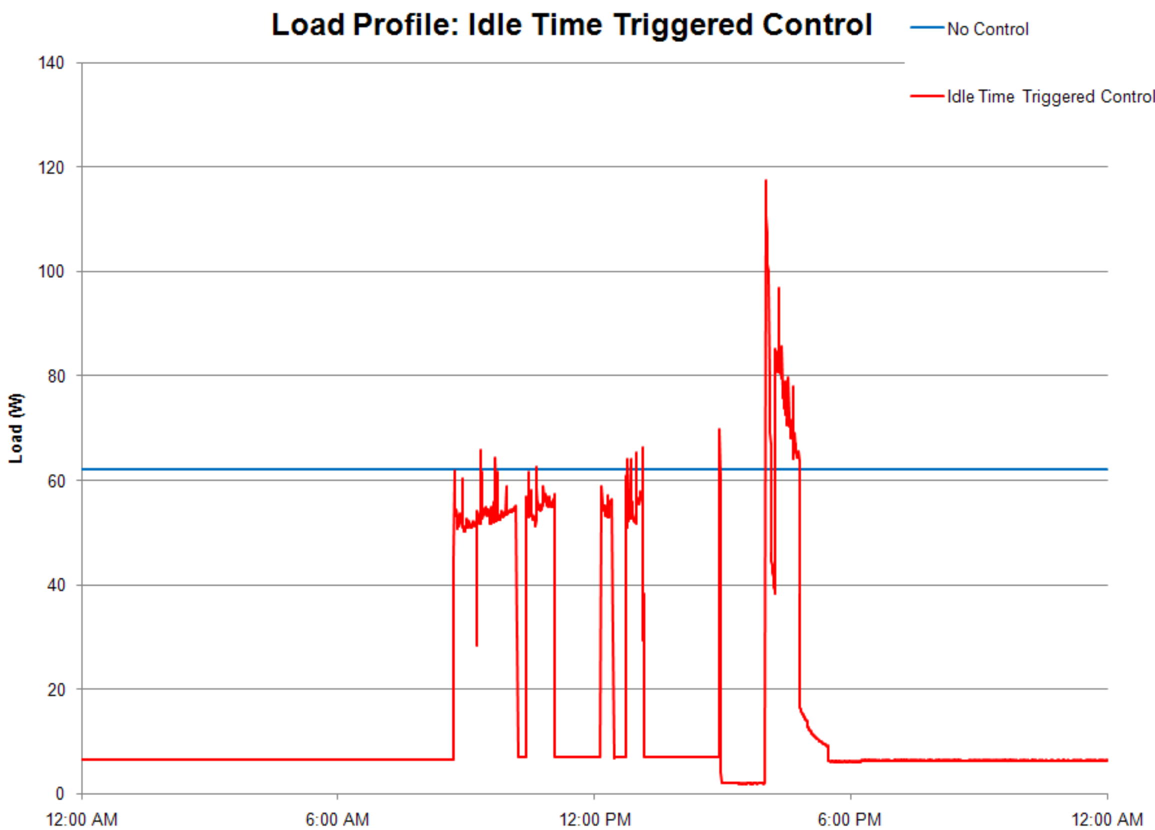

Figure 4–4 Load profile of a workstation with idle time triggered control only and good occupant behavior
(Credit: Michael Sheppy/NREL)

Compared to the "no control" workstation, the third-party software reduced the average power of the workstation by 47.5 W (14.5 W compared to 62 W). The remaining load (when the computer was in standby) was from the docking station and laptop charging.

4.1.2.1 Usability Issues

In our study, several users disabled the third-party power management program. Some regularly ran computer simulations that required their computers to run for long periods without user input. The third-party program forced their computers into standby before their simulations were complete because it was based on user inputs only and not computer processing. Ideally, the power management program would also account for computer processing to determine whether the computer is idle. Other users disabled the power management program because their computers took too long to emerge from standby state. On the other hand, the power management program caused almost no issues with users who had typical computing needs (creating and editing documents and spreadsheets, reading and sending emails, using the Internet). With more than a 75% reduction in the average workstation load by using standby, we strongly recommend that built-in automatic low-power state control be implemented on as many workstations as possible. If there are issues similar to the network activity experienced at NREL, we recommend user education to promote manual implementation of standby and investigating third-party programs to force low-power states.

4.1.3 Scheduling Control Device

Figure 4–5 shows the load profile of a workstation that used a power strip with digital timer control. The power strip was configured to energize the workstation only between 5:30 a.m. and 7:00 p.m. on weekdays. This workstation had the following additional controls implemented: no signal to monitors after 5 minutes of idle time; monitors with built-in automatic low-power state; and manual power management control. The workstation was configured so that all equipment (e.g., laptop, docking station, monitors, and task light) was powered by control outlets.

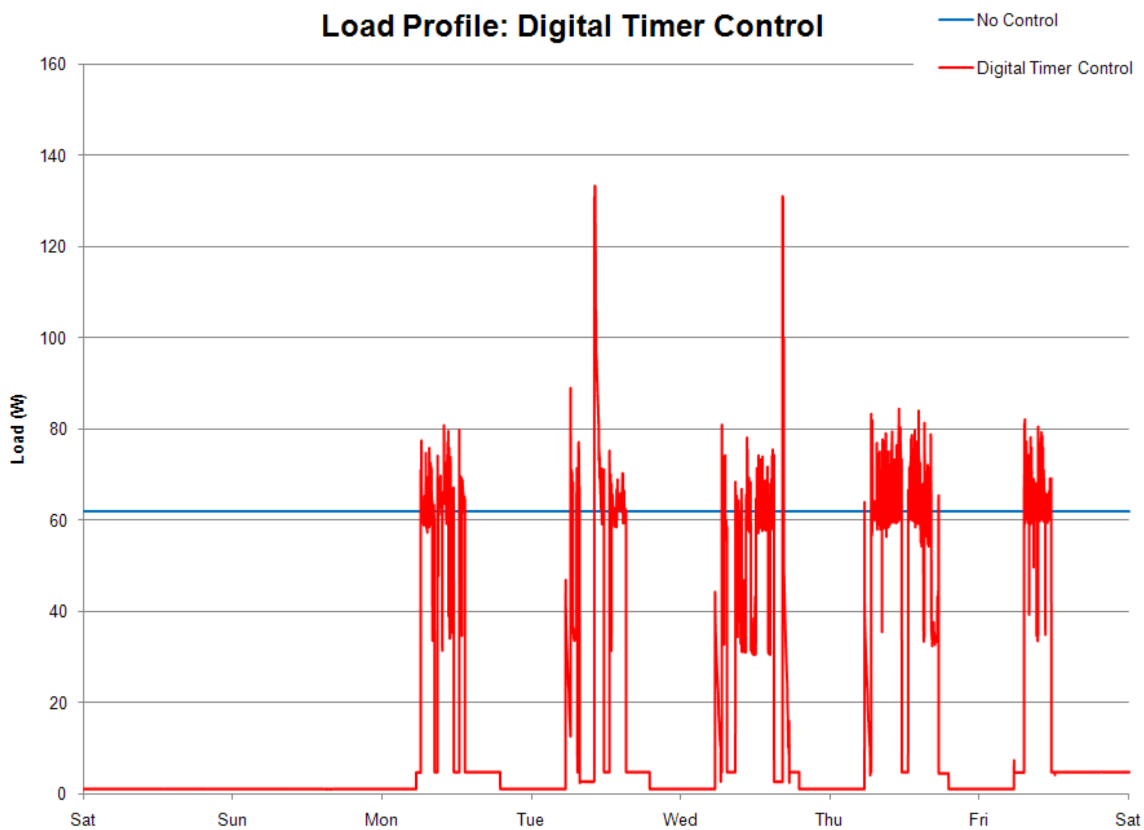

Figure 4–5 Load profile of a workstation with digital timer control only and good user behavior
(Credit: Michael Sheppy/NREL)

Compared to the "no control" workstation, the digital timer power strip reduced the average power of this workstation by 48.5 W (13.5 W compared to 62 W). It could be reduced further if the digital timer were configured to match the user's work schedule instead of a general 5:30 a.m. to 7:00 p.m., Monday through Friday schedule. Implementing either a consistent built-in automatic low-power state or third-party low-power state control (as discussed in Section 4.1.2) would yield maximum savings for the digital timer power strip control strategy.

Scheduling control is best suited for MELs that have a consistent, predictable usage pattern. One such MEL was the ice machine in the RSF's coffee kiosk. A power strip with digital timer control was configured to energize its outlets between 5:15 a.m. and 3:00 p.m. weekdays. This gave the ice machine enough time to make ice in the morning before the coffee kiosk opened

(7:00 a.m.). The machine was de-energized at the same time that the coffee kiosk closed every day (3:00 p.m.). Figure 4–6 is the measured daily load profile of the ice machine with and without scheduling control.

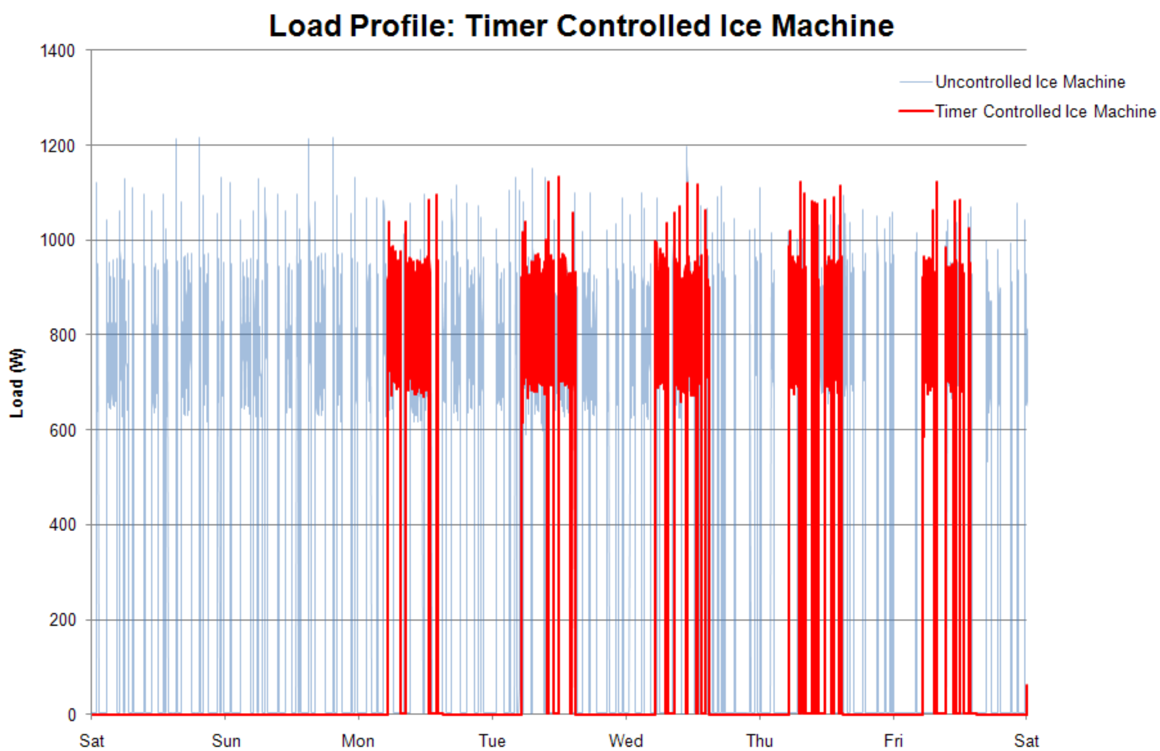

Figure 4–6 Load profile of the ice machine in the RSF's coffee kiosk
(Credit: Chad Lobato/NREL)

The digital timer-controlled power strip reduced the average power of the ice machine from 327 W to 157 W, a 52% savings. The savings came without impacting the quality of ice production during business hours.

4.1.3.1 Usability Issues

Very few users had usability problems with their workstations being controlled by a digital timer. The default configuration was to have all the workstation outlets controlled by the digital timer. Users who needed to run computer simulations on their laptops overnight found in the morning that the battery had fully discharged. This was corrected by plugging the laptop into an "always on" outlet and leaving the other workstation equipment to be controlled by the digital timer.

Some digital timer power strips have an override function that bypasses the digital timer control; however, unless the user turns off the override function, the automatic scheduling control will not be implemented.

4.1.4 Load-Sensing Control Device

4.1.4.1 Universal Serial Bus Load-Sensing Control Device

A USB load-sensing power strip senses when a computer's USB port is de-energized when the computer transitions to a standby or off state. When this occurs, the power strip cuts all power to workstation outlets. In our study, the power strip was configured to monitor one of the USB ports on a laptop. Figure 4–7 is the measured daily load profile of a workstation that used a USB load-sensing power strip. This workstation had the following additional controls implemented: no signal to monitors after 5 minutes of idle time; monitors with built-in automatic low-power state; and manual power management control. The workstation was configured so that all equipment (e.g., laptop, docking station, monitors, and task light) was powered by control outlets.

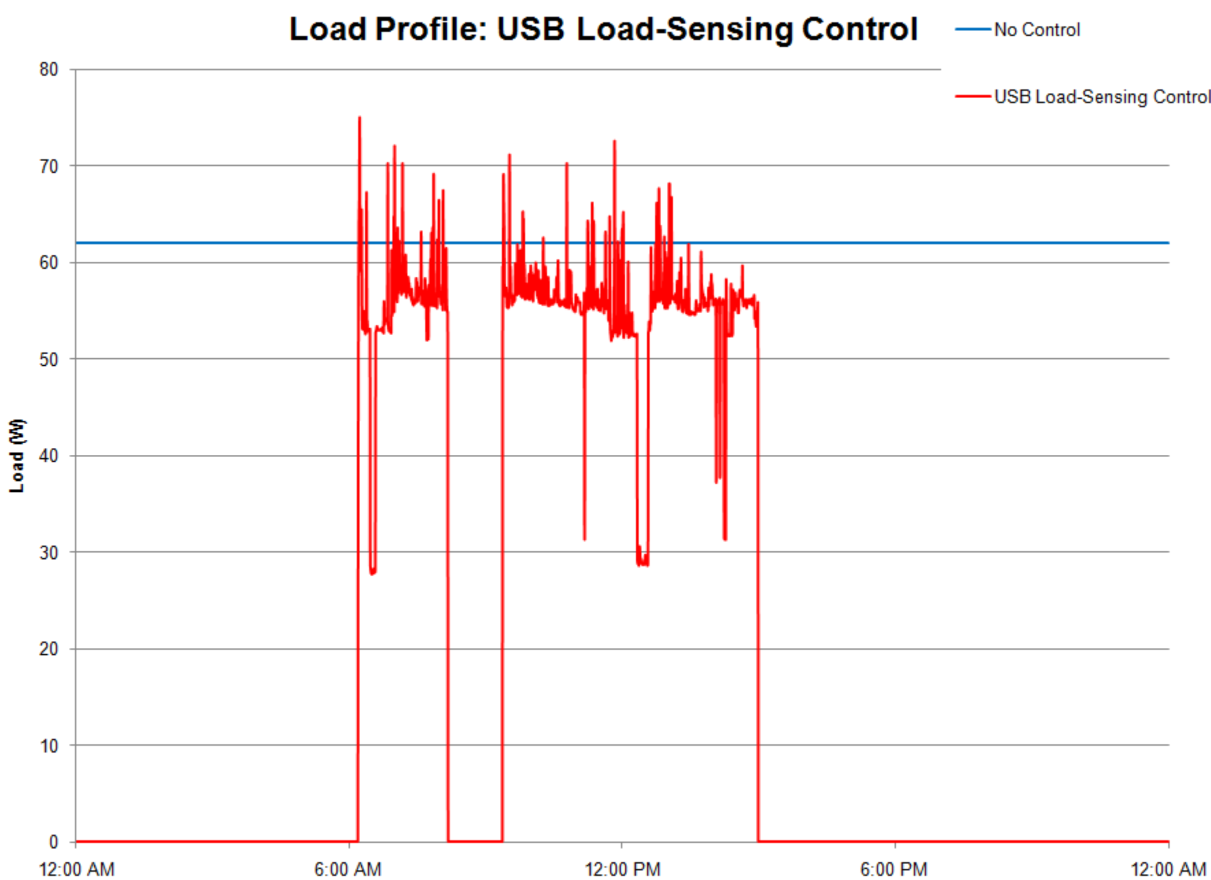

Figure 4–7 Load profile of a workstation with USB load-sensing control only and good user behavior
(Credit: Michael Sheppy/NREL)

The user of this workstation put his laptop into standby only once per day. The average load was 17 W (a 45-W saving over the "no control" workstation).

4.1.4.1.1 Usability Issues

No issues were reported for this control device.

4.1.4.2 Plug Load-Sensing Control Device

A plug load-sensing power strip senses when there is a change in the power draw on an outlet because the plugged-in MEL is transitioning from an in-use state to a low-power state. When this event occurs, the power strip cuts all power to workstation outlets. In our study, the power strip was configured to monitor the plug that powers the laptop docking station. Figure 4–8 shows the measured daily load profile of a workstation that used a plug load-sensing power strip. This workstation had the following additional controls implemented: no signal to monitors after 5 minutes of idle time; monitors with built-in automatic low-power state; and manual power management control. The workstation was configured so that the computer and docking station was powered by the sensing outlet and the rest of the equipment (e.g., monitors and task light) was powered by control outlets.

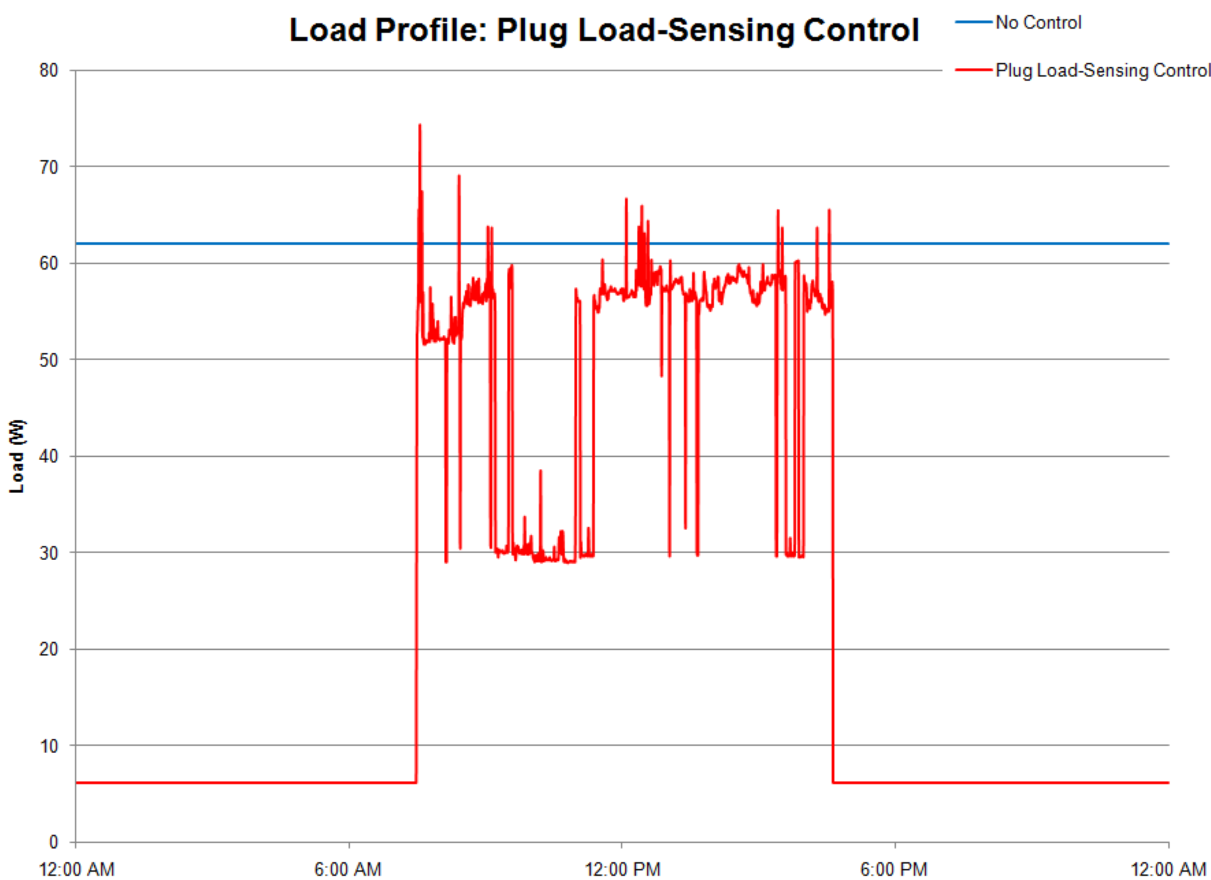

Figure 4–8 Load profile of a workstation with plug load-sensing control only and good user behavior
(Credit: Michael Sheppy/NREL)

The user of this workstation put his laptop into standby only once per day. The average load was 22 W (a 40-W saving over the “no control” workstation).

4.1.4.2.1 Usability Issues

No issues were reported for this control device.

4.1.5 Occupancy Control Device

Occupancy control is not the most suitable for controlling computer power because power is interrupted periodically, independent of the state of a computer. An occupancy control power strip was used to control only the workstation task light because of the power interruption issue. Figure 4–9 shows the measured daily load profile of a task light that used an occupancy control power strip.

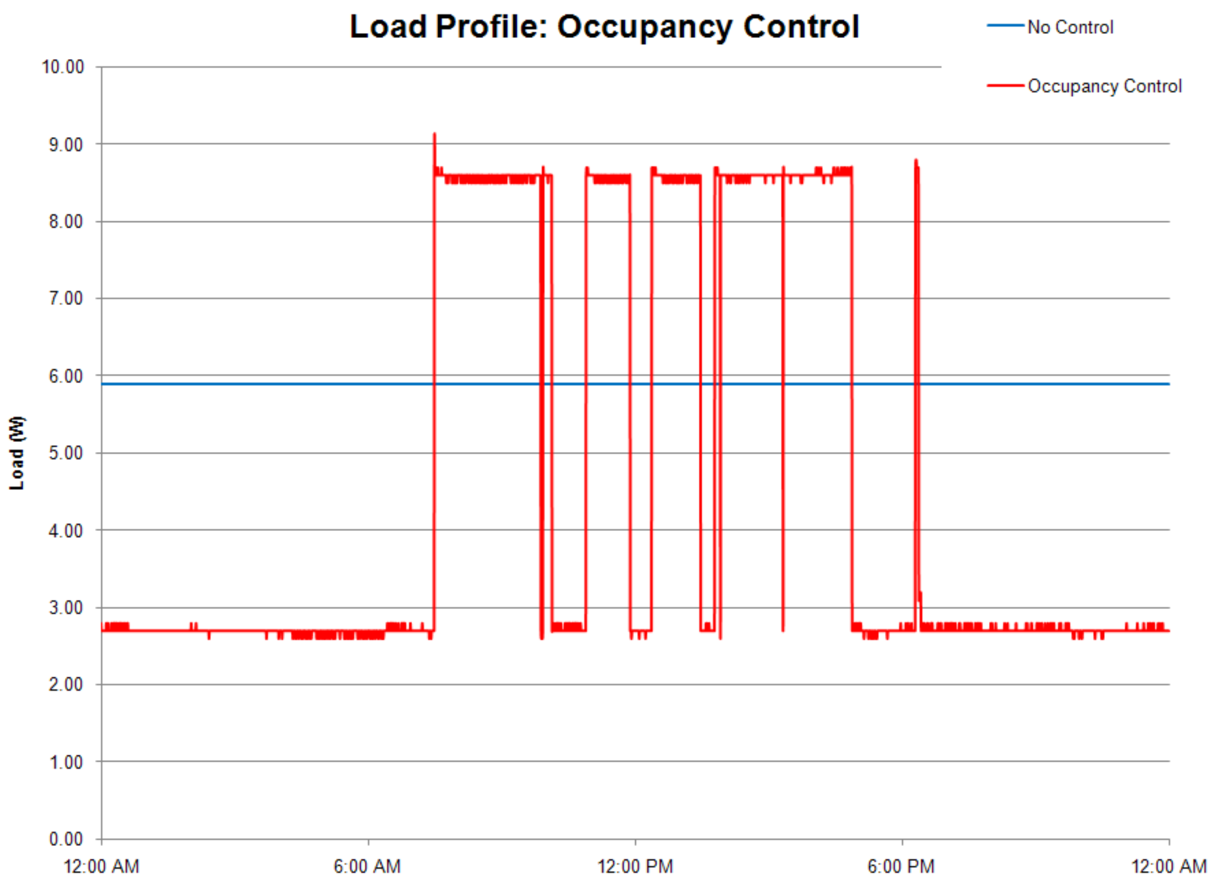

Figure 4–9 Load profile of a task light with occupancy control only
(Credit: Michael Sheppy/NREL)

This task light had an average load of 4.6 W (a 1.2-W saving over the "no control" task light) because of the occupancy control power strip's parasitic load (2.7 W).

4.1.5.1 Usability Issues

The main complaint about the tested occupancy control power strip was that it did not always detect movements. Most users turned the no-motion-power-off delay on their power strips to 15 minutes. Repositioning the occupancy sensor also helped improve movement detection.

4.1.6 Manual On, Vacancy Off Control Device

Manual on, vacancy off control devices were not studied because they are not currently available.

4.1.7 Manual Control

Manual control of MELs can take many forms, including mechanical switches tied to wall outlets, remote controls, and power switches built into the equipment. Manual control can be used to power down a device or just put it into a low-power state. However, it relies on "good" user behavior to be effective. Three power strips with remote switches were studied. Two used a wireless remote placed on the desktop to allow manual control of the power strip outlets. The last device used a wired remote. In all cases, the power strips offered a remote that gave users a conveniently located manual switch to de-energize the outlets. The primary difference between these power strips and a conventional power strip is that the manual switch is located on the desktop rather than under the desk, on the floor, behind a cabinet, or other less convenient locations. Figure 4–10 is the measured daily load profile of a workstation that used a remotely controlled power strip. This workstation had the following additional controls implemented: no signal to monitors after 5 minutes of idle time; monitors with built-in automatic low-power state; and manual power management control. The workstation was configured so that all equipment (e.g., laptop, docking station, monitors, and task light) was powered by control outlets.

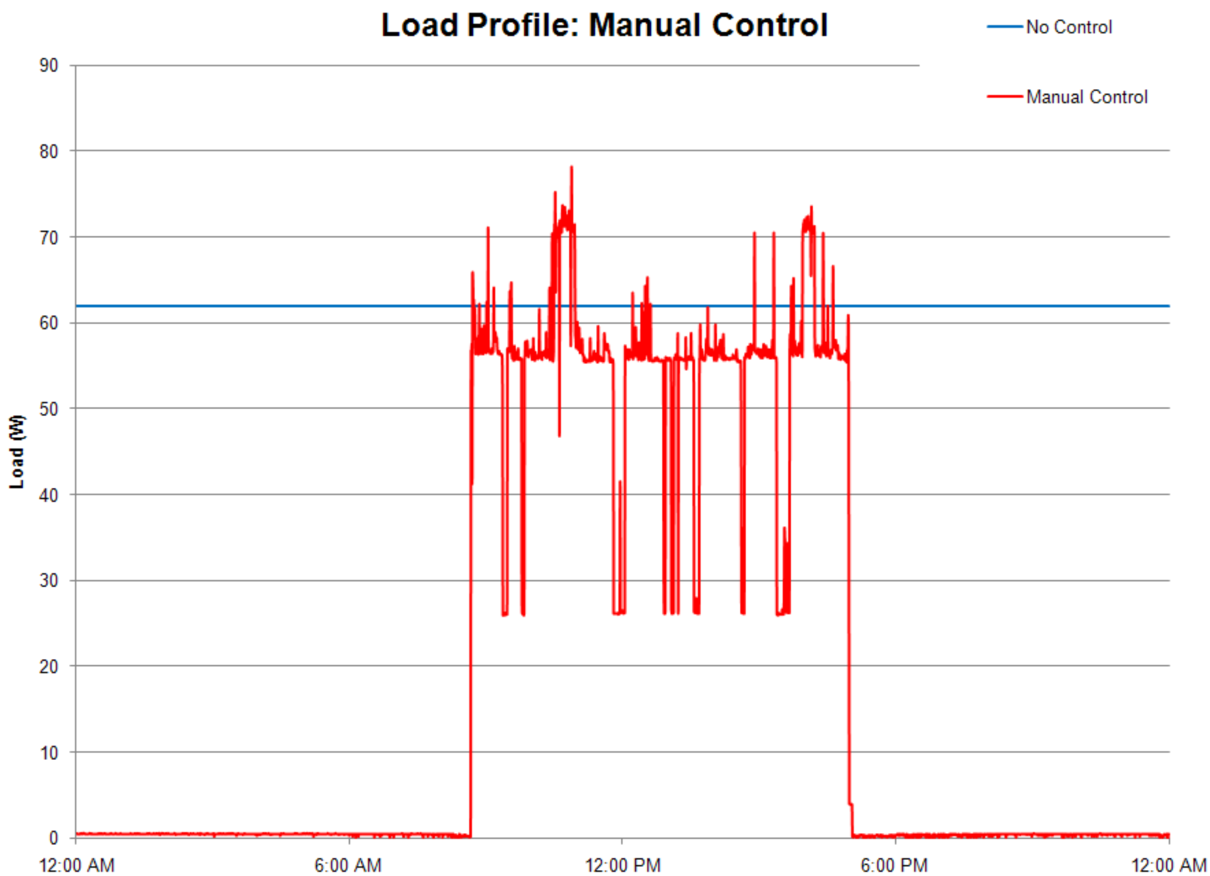

Figure 4–10 Load profile of a workstation with manual control only "good" behavior
(Credit: Michael Sheppy/NREL)

The user of this workstation used the remote control power switch only once per day. His average load was 19 W (a 43-W savings over the "no control" workstation).

5.0 Equipment and Strategies Implemented in the Research Support Facility

The following energy-efficient equipment and strategies were implemented in the RSF to meet occupant needs and reduce MELs. Control solutions implemented in the RSF will be highlighted.

5.1.1 Server Room

5.1.1.1 Research Support Facility Server Room Equipment and Controls

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.

In the RSF data center, the lighting is controlled using manual on, vacancy off light switches. The blade servers have variable-speed fans that can ramp up or down to meet cooling needs.

5.1.1.2 Equipment and Operation Guidelines for Server Rooms

UPSs serve two main functions in server rooms: (1) they condition line power; and (2) they maintain power delivery during power outages until the backup generator kicks on. Typical legacy UPS efficiency is around 80%; these devices produce extra heat that requires additional cooling. When procuring a new UPS, the following features are critical:

- 95% + energy efficiency
- Scalable design
- Built-in redundancy
- End user serviceable
- Provide uptime until the backup generator starts
- Meet the efficiency guidelines of the Server System Infrastructure initiative, which set open industry specifications for server power supplies and electronic bays.

The UPS should be loaded so it operates at peak efficiency. Information about the relationship between loading and efficiency is found in the manufacturer's documentation.

Energy-efficient power distribution units should be used to distribute power. To further reduce the power footprint, blade servers should be procured that use variable-speed fans and energy-efficient power supplies, and run virtualization software (to decrease the required number of physical servers).

Hot aisle containment dramatically reduces cooling loads by preventing supply and return air from short circuiting (mixing with each other). This strategy also provides the opportunity for waste heat recovery; however, it is an involved change to the server room that is best suited for new construction and retrofit projects that can afford the downtime to arrange the cabinets.

5.1.2 Workstations

5.1.2.1 Research Support Facility Workstation Equipment and Controls

The MEL audit of previously occupied NREL office space revealed numerous opportunities to reduce MELs 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 displays or cathode ray tube displays. To reduce computer energy consumption, 90% of the RSF occupants use laptop computers with LED backlit LCD monitors. Figure 5–1 shows the measured load profile of a laptop computer and two, 22-in. LED backlit LCD monitors.

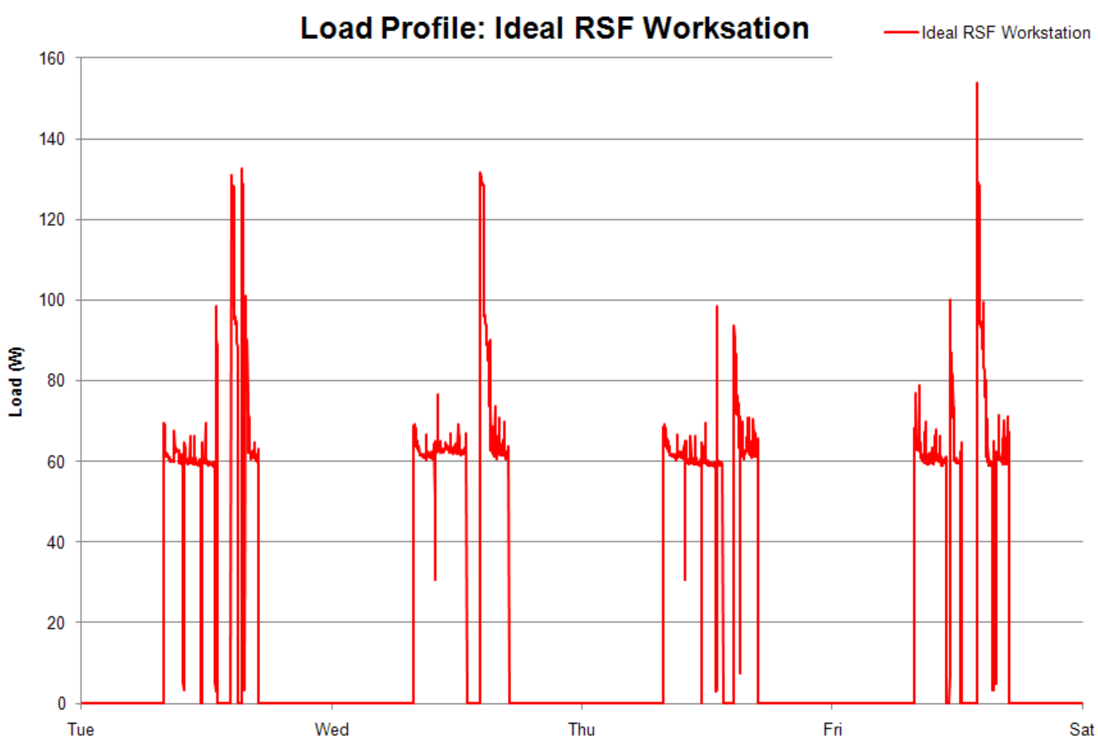

Figure 5–1 Load profile of a laptop computer and two monitors with ideal control and user behavior
(Credit: Chad Lobato/NREL)

The average power draw for this laptop and display combination was 54 W during occupied hours and 5 W during unoccupied hours. Further savings during unoccupied hours are achieved with a load-sensing controlled outlet on a power management surge protector to eliminate the parasitic load of the docking station (see Figure 5–1).

The previous strategy for dealing with idle computers was to lock them out after 15 minutes and display a security screensaver. The screensaver increased average power by 5 W compared to an idle state (30–35 W for a laptop locked out in the security screensaver versus 25–30 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 from 25–30 W to 5 W. To further reduce computer energy use, the computers used in the RSF have been set to put the monitor into standby after five minutes of idle time, and then the computer into standby after 15 minutes of idle time. As previously stated, the built-in standby functionality has not performed as intended. The users have been instructed to manually force standby to reduce energy use.

Additional equipment in the previously occupied workspaces 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. These items received power from standard six-plug surge protectors.

The RSF workstations feature efficient 6-W LED task lighting and voice over Internet protocol phones that consume a constant 2 W. NREL IS power settings turn off the LCD screens on these phones after 1 minute of idle time. All other items have been discouraged or allowed only case by case as approved. Some users initially wished to bring the additional equipment from the previous office space. NREL provided employees with educational documentation that discussed the buildings specifics and goals and emphasized the impact the building occupants have on overall energy use. The educational effort helped employees understand why the equipment was being limited and increased buy-in.

Power at the workstation was intended to be controlled by a load-sensing power strip that has a 1.5-W parasitic load. It has two pairs of controlled outlets and four always-powered outlets. It is designed so that when power draw on one of the paired sensor outlets drops, power is cut to the senor outlet and paired controlled outlet. It is desktop mounted so the main power button is easily accessible. The device was evaluated and compared to other available devices and determined to be a suitable option; however, it was selected and implemented before the evaluation process discussed in this report was developed. In practice, the installed control devices have not performed as expected. Its load sensing is inconsistent, causing equipment to be de-energized at inappropriate times or not at all. This has caused some usability issues and building occupants are bypassing the control outlets and using only the always-powered outlets. Also, its parasitic load is higher than that of the equipment it controls.

5.1.2.2 Equipment and Operation Guidelines for Workstations

Workstations represent a significant fraction of office building MELs and overall building energy use. Moorefield et al. (2008) found that computers and monitors accounted for the largest share of MELs energy use in office spaces. Computers are usually their biggest energy users. An in-use standard desktop computer will consume 100 W on average (Lobato et al. 2011). Replacing desktop computers with laptop computers, which have an average power draw of 30 W while in use, will save considerable energy. It is important for the champion to work with information technology representatives to implement computer power options to save energy. Computers that sit idle or that run screensavers when they are not being used waste considerable energy. The power options should be set so the computers and monitors go into standby or sleep mode after 15 minutes of idle time. If built-in functionality is ineffective, third-party software solutions should be implemented to achieve reliable standby operation.

Monitors are the next-largest energy consumer at workstations. A powered-up cathode ray tube monitor can draw as much as 70 W. Replacing old monitors with energy-efficient LCD monitors saves energy. To achieve the greatest savings, LED backlit LCD monitors should be used. Given the current state of technology, a powered-up 19-in. fluorescent backlit LCD monitor will use approximately 30 W, compared to a powered-up 19-in. LED LCD monitor that uses 10 W.

Depending on the number of workstations, replacing computers and monitors can be a very costly measure. If capital is not available to replace all equipment at once, a staged approach or efficient replacement plan should be implemented. Equipment can be replaced in stages as the project budget allows, or when older pieces fail, they can be replaced by new, energy-efficient equipment.

Incandescent or fluorescent tube task lighting should be replaced by efficient compact fluorescent lamps or LED task lighting. Replacing standard phones with low-power voice over Internet protocol phones provides additional workstation savings.

Office workstations are often equipped with personal single-function devices such as printers, scanners, and fax machines. Consolidating these items into shared multifunction devices reduces MELs and saves energy. Further savings can be realized by enabling the power option settings on the multifunction devices to go into standby after 15 minutes of idle time.

5.1.3 Break Rooms and Kitchens

5.1.3.1 Research Support Facility Break Room and Kitchen Equipment and Controls

A key design team contribution to reducing MELs included maximizing space efficiency in shared areas. The previously occupied NREL office buildings provided underutilized break rooms with refrigerators, microwaves, coffee pots, drinking fountains, and vending machines. The RSF features the same amenities, but each break room is better utilized by serving approximately 60 occupants compared to 40 in previously occupied NREL buildings, which reduced the number of energy-consuming appliances. Further savings are achieved with efficient refrigerators (48 W average load) and by eliminating mechanically cooled drinking fountains. The kitchens 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.

The nonrefrigerated kitchen appliances are controlled by digital timer-controlled power strips.

5.1.3.2 Equipment and Operation Guidelines for Break Rooms and Kitchens

Old refrigerators can waste energy. Aging, inefficient refrigerators should be replaced with the most efficient full-size ENERGY STAR refrigerators. It is important to remove all personal mini-refrigerators and underused full-size refrigerators. The MELs audit performed on the NREL coffee kiosk revealed that mini-refrigerators can use the same energy as full-size refrigerators.

Items such as coffee pots, toasters, and microwaves should be upgraded with units that have limited parasitic loads from status LED lights or displays. In many cases, the lights and displays are not needed and waste energy. These items should be powered by electrical outlet timers so they are powered down during unoccupied hours.

Vending machines can consume a large amount of energy. The first step in savings is to remove underused machines and to replace aging, inefficient vending machines with the most efficient ENERGY STAR equipment. Removing the display lighting yields additional energy savings. Deru et al. (2003) found that combining a load-managing device with delamping could reduce energy consumption in vending machines by 45%–55%. Many such devices are commercially available; the simplest is an electrical outlet timer.

The drinking fountain coolers should be removed or disconnected. Bottled water coolers should also be removed.

5.1.4 Elevators

5.1.4.1 Research Support Facility Elevators and Controls

The RSF employs energy-efficient regenerative traction elevators rather than the standard hydraulic elevators that typically operate in low-rise office buildings. Each 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 and windows for daylighting and mountain views.

Occupancy-controlled car lighting and ventilation are installed in RSF elevators. This helps to reduce loads when the car is unoccupied.

5.1.4.2 Equipment and Operation Guidelines for Elevators

Elevator car lighting and ventilation are typically powered whether or not the car is occupied. Adding occupancy sensors to control lighting and ventilation will save energy.

5.1.5 Telecommunications Room Equipment

5.1.5.1 Research Support Facility Telecommunications Room Equipment and Controls

Standard equipment is used and no control strategies are implemented in the RSF.

5.1.5.2 Equipment and Operation Guidelines for Telecommunications Rooms

Typical telecommunications rooms provide continuous power to all Ethernet switches and ports. To reduce MELs, these switches and ports should be intelligently powered and enabled based on occupant needs.

5.1.6 Conference Room Equipment

5.1.6.1 Research Support Facility Conference Room Equipment and Controls

Conference rooms use video projectors, high-definition multimedia interface switchers and extenders, Blu-ray and DVD players, wireless microphone systems, integrated controllers, speaker systems, audio amplifiers, and electric projector screens as standard equipment. MELs controls were not implemented for the RSF conference rooms.

5.1.6.2 Equipment and Operation Guidelines for Conference Rooms

Conference rooms are subject to varying use schedules. A key to MELs energy use reduction is to 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. Beyond load control, the space should be outfitted with energy-efficient equipment. LED backlit LCD televisions and energy-efficient audiovisual equipment should be used. Policies should be implemented to address equipment that is supplied by individual users and that is only temporarily powered. The policies would require use of efficient equipment that is powered only when needed.

5.1.7 Small-Scale Food Service Areas

5.1.7.1 Research Support Facility Equipment and Controls

A coffee kiosk provided a variety of hot and cold beverages and food to occupants in three of NREL's previous office buildings. The espresso machine and water heater were powered up all day and all night. 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, it 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. Two coffee brewers automatically reduce the water temperature in their boilers when idle. Mechanical switches 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 an electrical outlet timer to turn off during unoccupied hours, which reduces continuous power draw from 327 W to 110 W. The RSF has two ENERGY STAR soda vending machines and one snack vending machine that feature efficient LED display lighting, which is controlled by occupancy sensors.

5.1.7.2 Equipment and Operation Guidelines for Small-Scale Food Service Areas

As with the break rooms and kitchens, replacing aging, inefficient equipment with the most efficient ENERGY STAR rated equipment will save energy. Food service areas present unique challenges because they are often outfitted and operated by outside vendors. It is important to set contractual requirements and to work with vendors to ensure energy-efficient MELs and operations in these areas. For example, refrigerators should be required to have solid front doors rather than glass doors. A glass door refrigerator can use twice the energy of a similarly sized solid front refrigerator. Multiple mini-refrigerators should be consolidated into fewer full-size refrigerators to save energy.

Food service equipment can have large parasitic loads when the space is unoccupied. Electrical switches, or a similar method, should be provided to easily disconnect power to all nonessential equipment during nonbusiness hours. Cutting the loads during nonbusiness hours drastically reduces annual energy use. Contractual requirements should be set to ensure outside vendor equipment is disconnected and powered down during nonbusiness hours.

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

5.1.8 Miscellaneous

5.1.8.1 Equipment and Operation Guidelines for Miscellaneous Areas

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. Compact shelving manufacturers offer manual models that provide adequate gearing in the hand crank to limit the effort needed to move the shelving.

Management policies should be implemented to address MELs. They should minimize or eliminate 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, and provide a process for addressing atypical circumstances and granting exceptions.

Items such as lobby displays, ice machines, and exercise equipment can be effectively controlled by outlet timers. The timers should be configured so the equipment is powered up 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 unoccupied times. These panels also allow for easy energy submetering.

Plug loads often depend heavily on occupant behavior and equipment operation. To maximize savings, office building owners need to educate employees about the energy impacts of their behaviors.

6.0 Conclusion

MELs are found in every building type. In a minimally code-compliant building, they may account for up to 25% of the total building energy use, but as buildings become more efficient, that number can increase to as high as 50%. Occupants in office buildings are typically seated at their desks for 10% of the year. Using a control strategy to match plug load use to occupancy is a huge untapped potential for energy savings.

The importance of controlling MELs was low in the past, as the energy use has historically been small relative to other building energy end uses. Also, the loads vary drastically, which complicates the control. As the other building systems become more efficient, the energy performance of buildings is becoming more driven by occupant behavior and the resulting MELs energy use. MELs are unique loads that provide multiple functions and services, and are operated in many different ways. Building design teams are rarely held accountable for plug loads because they are owner specified and are highly occupant dependent. At the same time, building owners and occupants do not always know what is required to specify, procure, and operate MELs energy efficiently.

To complicate matters, manufacturers are starting to bring products to market that claim to reduce MEL energy use. Each claims savings, but few provide the detailed information needed to make an educated decision about the best control strategy for a given MEL.

The same MEL type may have completely different use patterns from one location to another. Control schemes must therefore be tailored to the MELs. Presently, no single device can control all MELs properly. This, paired with the ever-growing market of control devices with limited product information, drives the need for the guidance provided by the flowchart in Figure 2–1 through Figure 2–4. The flowchart removes some of the confusion associated with MELs controls. It provides a roadmap for users to arrive at an appropriate control. The user can then evaluate a condensed list of available devices that offer the appropriate control to determine which best meets their needs.

In existing buildings, equipment needs to be inventoried and benchmarked as discussed in Section 2.1. This process will help building owners and operators understand what is needed to meet the occupants' business needs. Then these needs should be met as efficiently as possible. Only then can the control provide the highest energy savings.

Computers are unique and challenging MELs; they are also among the most common MELs in commercial buildings and therefore require specific attention. In office buildings, computers quickly become a major energy consumer because they are typically provided for all building occupants. Reducing the energy use of computers when not in use has the potential of providing a significant MELs energy saving in commercial buildings.

Computers are generally set up at workstations that feature multiple secondary devices. When energy-efficient equipment such as LED backlit computer monitors and LED task lights replace equipment with dated technology, the parasitic load is reduced to the point that controlling the computer becomes the main concern.

A desktop computer should not be de-energized without going through a proper shutdown procedure. A laptop computer can be de-energized because of the built-in battery backup, but if it is left in an idle state the battery can fully discharge before a proper shutdown procedure is performed. Thus, computers should not be controlled by scheduling or occupancy-based control devices. They also should not be set up as a secondary device that is controlled by load sensing on a primary device.

Computers are primary devices that must rely on manual control, built-in low-power states, or third-party hardware and software solutions that perform the needed tasks to transition them from a ready-to-use state to a low-power state. Manual control can be effective, but it is not consistent and can vary depending on the users. Additional control should be implemented to account for this inconsistency. This is where the built-in low-power state should provide the main control needed for computers. Unfortunately, this control can become as inconsistent as manual control. Once computers are configured to meet the user needs, installed programs could maintain processes that do not allow the computer to transition to the low-power state.

Ideally, the built-in functionality would operate consistently and provide the control needed to decrease energy consumption in computers. This, however, is not the case. Third-party programs can be used to improve the built-in functionality. Hardware and software options are available that force a transition to a low-power state based on user input. Other software options use computer idle time and scheduling to force the transition without relying on user input. These solutions are temporary fixes until the built-in functionality can be improved to work consistently in all installations. Computer manufacturers need to focus on this to enable the greatest MELs energy savings. Once computers can reliably and consistently go into low-power states, they can then be used reliably as the sensed (primary) device in a load-sensing control scheme to control secondary devices.

7.0 References

Deru, M.; Torcellini, P.; Bottom, K.; Ault, R. (2003). *Analysis of NREL Cold-Drink Vending Machines for Energy Savings.* Golden, CO: National Renewable Energy Laboratory: NREL/TP-550-34008. www.nrel.gov/docs/fy03osti/34008.pdf.

Frank, S.; Lobato, C.; Long, N.; Gentile Polese, L.; Rader, E.; Sheppy, M.; Smith, J. 2010. *Monitoring and Characterization of Miscellaneous Electrical Loads in a Large Retail Environment*. Golden, CO: National Renewable Energy Laboratory, NREL/TP-5500-50044.

General Espresso Equipment Corporation. (2009). "Astoria Presents: Plus 4 You, The First Energy Saving Machine in the World." *21st Annual SCAA Exposition*, Atlanta, GA.

Invent Technology Solutions Ltd. (2011). *Ecobutton one small click, one big change.* United Kingdom. http://www.eco-button.com/.

KONE Corporation. 2006. *KONE Green Calculator – Compare Hydraulic Elevators with KONE EcoSpace*. Finland. www.kone.com/media/en_US/green/index.html.

Lobato, C.; Pless, S.; Sheppy, M. (2011). *Reducing Plug and Process Loads for a Large Scale, Low Energy Office Building: NREL's Research Support Facility.* Golden, CO: National Renewable Energy Laboratory. NREL/CP-5500-49002. www.nrel.gov/docs/fy11osti/49002.pdf.

McKenney, K.; Guernsey, M.; Ponoum, R.; Rosenfeld, J. (2010). *Commercial Miscellaneous Electric Loads: Energy Consumption Characterization and Savings Potential in 2008 by Building Type*. Lexington, MA: TIAX LLC. May. http://zeroenergycbc.org/pdf/2010-05-26%20TIAX%20CMELs%20Final%20Report.pdf.

Moorefield, L.; Frazer, B.; Bendt, P. (2008). *Office Plug Load Field Monitoring Report.* Durango, CO: Ecos.

Slawdog E-Solutions, Inc. (2003). *Smart Shutdown Classic Home Page.* http://www.slawdog.com/products/smartsd/index.aspx.

U.S. General Services Administration. (2006). *Workplace Matters*. Washington, DC: U.S. General Service Administration.

U.S. DOE, U.S. Department of Energy. (2009). *2009 Buildings Energy Data Book.* Washington, DC: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. http://buildingsdatabook.eere.energy.gov/.

Appendix A Scheduling Control Devices

Table A–1 is an extensive (but not exhaustive) list of MELs control devices utilizing scheduling that are commercially available as of July 2011. For those devices that were tested during this study, the parasitic loads were measured with a Watts Up? Pro ES meter. This meter has known inaccuracies, which are discussed by Frank et al. (Frank 2010).

Table A–1 MELs Control Devices That Utilize Scheduling

Control Type	Device Name	Features	Metering	Parasitic Load (W)		Number of Outlets
				Energized	De-Energized	
Scheduling	APC 6-Outlet Surge Protector with LCD Timer	Digital timer	No	Not tested	Not tested	6
	APC SurgeArrest Essential Power-Saving Timer Surge Suppressor	Digital timer	No	Not tested	Not tested	4
	Belkin Conserve Surge with Timer	Manual switch activated timer	No	0.1	0	8
	Coleman Cable Indoor 8 Outlet Power Strip with Timer	Mechanical timer	No	Not tested	Not tested	8
	Conserve Socket Energy Saving Outlet (F7C009)	Digital timer	No	Not tested	Not tested	1
	GE 7-Day Plug-In Digital Timer (15079)	Digital timer	No	Not tested	Not tested	2
	GE 7-Day Plug-In Digital Timer (15150)	Digital timer	No	Not tested	Not tested	1
	GE Digital Strip Timer (GE06694)	Digital timer	No	0.9	0.9	8
	Jetlun Appliance Module and Gateway	Software controlled schedules and wireless metering	Yes	1.1	1.1	1
	P3 Kill A Watt GT	Digital timer	Yes	Not tested	Not tested	1
	P3 Save a Watt	Digital timer	No	Not tested	Not tested	1
	ThinkEco Modlet	Software controlled schedules and wireless metering	Yes	0.3	0.3	2
	Tripp Lite Timer-Controlled ECO Home/Business Theater Surge Suppressor	Digital timer	No	Not tested	Not tested	7
	Visible Energy UFO Power Center	Software controlled schedules and wireless metering	Yes	Not tested	Not tested	4
	Westinghouse Dual Outlet Mechanical Timer (T00448)	Mechanical timer	No	Not tested	Not tested	2

Appendix B Load-Sensing Control Devices

Table B–1 is an extensive (but not exhaustive) list of MEL control devices utilizing load sensing that are commercially available as of July 2011. For those devices that were tested during this study, the parasitic loads were measured with a Watts Up? Pro ES meter. This meter has known inaccuracies, which are discussed by Frank et al. (2010).

Table B–1 MELs Control Devices That Utilize Load Sensing

Control Type	Device Name	Features	Metering	Parasitic Load (W)		Number of Outlets
				Energized	De-Energized	
Load sensing	Belkin Conserve Smart AV	Outlet based load sensing	No	0	0	8
	Bits Charging Station 10 (LPG-3)	Battery charge level based load sensing	No	Not tested	Not tested	10
	Bits Charging Station 7 Outlet (BIT-SPG3)	Battery charge level based load sensing	No	Not tested	Not tested	7
	Bits Energy Saving Smart Strip with Volt Sensing (LEG3)	Outlet based load sensing	No	Not tested	Not tested	10
	Coleman Cable Systems 10 Outlet Smart Strip (04946)	Outlet based load sensing	No	Not tested	Not tested	10
	Coleman Cable Systems 6 Outlet Smart Strip (04949)	Outlet based load sensing	No	Not tested	Not tested	6
	EcoStrip USB 2.0	USB based load sensing	No	0	0	6
	Euroguys DSi Energy Saver Power Strip	Outlet based load sensing	No	Not tested	Not tested	5
	Ideative Home Office Energy Saving Surge Protector (ES1654W-05)	Outlet based load sensing	No	Not tested	Not tested	6
	iGo Power Smart Tower	Outlet based load sensing	No	1.5	0.1	8
	NuGiant Power Strip (32001)	Outlet based load sensing	No	Not tested	Not tested	6
	Smart Strip (LCG4)	Outlet based load sensing	No	Not tested	Not tested	10
	SurgExpert 6 Outlet Smart Surge Strip	Outlet based load sensing	No	Not tested	Not tested	6
	TrickleStar 6 Outlet Advanced Power Strip (180SS-US-6XX)	Outlet based load sensing	No	Not tested	Not tested	6
	Visible Energy UFO Power Center	Outlet based load sensing	Yes	Not tested	Not tested	4
	Woods Ind. Ten Outlet Smart Surge Protector Strip (04940)	Outlet based load sensing	No	Not tested	Not tested	10

Appendix C Occupancy Control Devices

Table C–1 is an extensive (but not exhaustive) list of MEL control devices utilizing occupancy sensing that are commercially available as of July 2011. For those devices that were tested during this study, the parasitic loads were measured with a Watts Up? Pro ES meter. This meter has known inaccuracies, which are discussed by Frank et al. (2010).

Table C–1 MELs Control Devices That Utilize Occupancy Sensing

Control Type	Device Name	Features	Metering	Parasitic Load (W)		Number of Outlets
				Energized	De-Energized	
Occupancy	Isole Control Tower Power Strip (PS-305)	Occupancy	No	Not tested	Not tested	6
	Isole Power Station 1	Occupancy	No	Not tested	Not tested	1
	Isole Power Strip with Personal Sensor (IDP-3050)	Occupancy	No	2.6	2.6	8

Appendix D Manual Control Devices

Table D–1 is an extensive (but not exhaustive) list of MEL control devices utilizing manual switching that are commercially available as of July 2011. For those devices that were tested during this study, the parasitic loads were measured with a Watts Up? Pro ES meter. This meter has known inaccuracies, which are discussed by Frank et al. (Frank 2010).

Table D–1 MELs Control Devices That Utilize Manual Switching

Control Type	Device Name	Features	Metering	Parasitic Load (W)		Number of Outlets
				Energized	De-Energized	
Manual	Belkin Conserve Surge with Timer	Manual switch activated timer	No	0.1	0	8
	Belkin Conserve Switch	Wireless manual switch	No	0.9	0.1	8
	Lightning Switch Continental Transmitter and Plug-In Receiver	Wireless manual switch	No	0.1	0.6	1
	Philips 10-Outlet Home Theater Surge Protector (SPP5107C/17)	Wireless manual switch	No	Not tested	Not tested	10
	Practecol Power Strip with Remote	Wireless manual switch	No	Not tested	Not tested	8
	Tripp Lite Isobar 8 RM Surge Supressor	Manual switch	No	Not tested	Not tested	8
	Westinghouse Light Switch Remote (T00412)	Wireless manual switch	No	Not tested	Not tested	1
	Woods 6 Outlet Power Strip with Foot Switch (553574)	Manual switch	No	Not tested	Not tested	6

Appendix E Minimum Miscellaneous Electrical Load Power Draw to Justify Control

Sections E.1 through E.5 show the minimum average power draw for a MEL that is not in use that can be cost effectively controlled by a control device. The graphs were developed assuming 9 hours of operation per work day and 250 work days per year. They vary by the assumed payback period. For a given utility rate, all MELs with an average power while not in use above the line should be controlled. If a MEL's power is below the line, controlling it is not cost effective. Figure E–1through Figure E–5 show 1-, 3-, 4-, 5-, and 10-year paybacks.

E.1 One-Year Payback Period

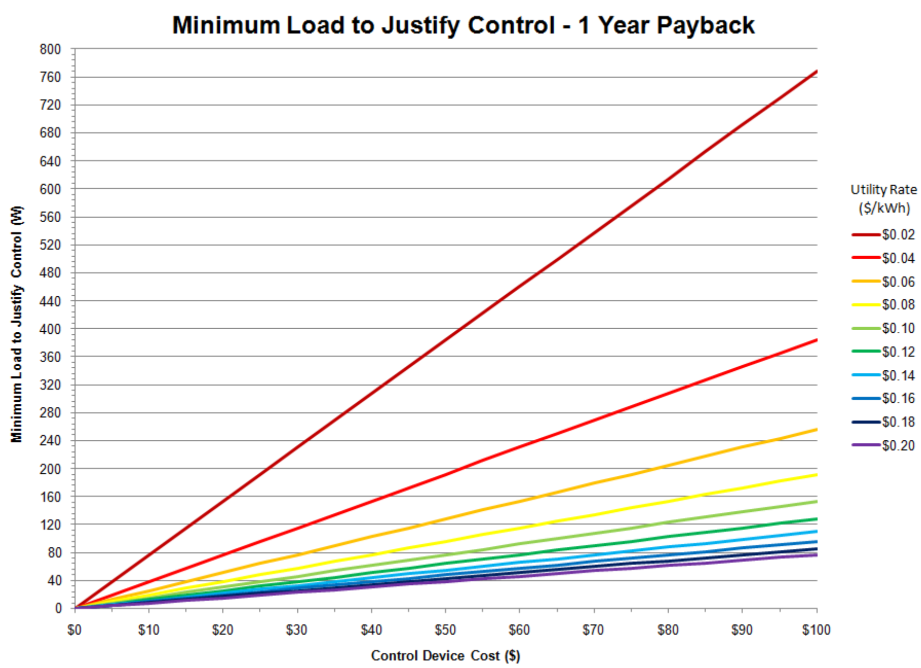

Figure E–1 Minimum load that can be cost-effectively controlled by a control device – 1-year payback

(Credit: Chad Lobato/NREL)

E.2 Three-Year Payback Period

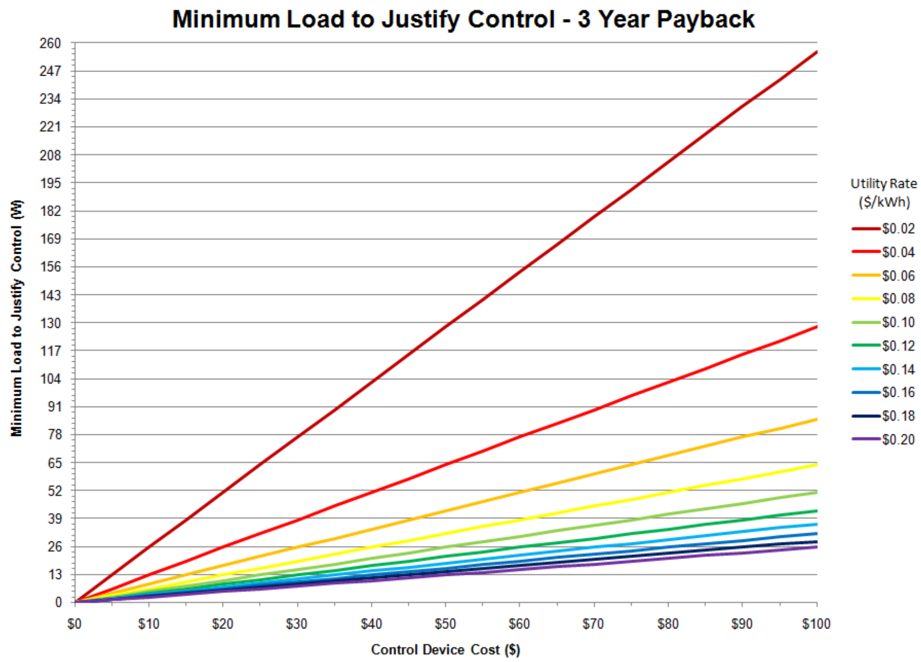

Figure E–2 Minimum load that can be cost-effectively controlled by a control device – 3-year payback
(Credit: Chad Lobato/NREL)

E.3 Four-Year Payback Period

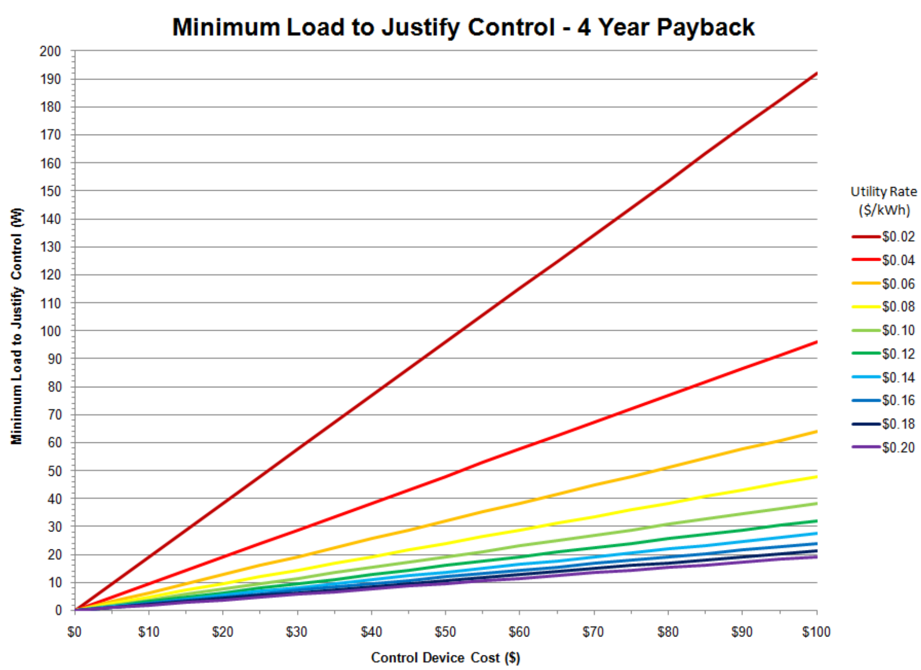

Figure E–3 Minimum load that can be cost-effectively controlled by a control device – 4-year payback
(Credit: Chad Lobato/NREL)

E.4 Five-Year Payback Period

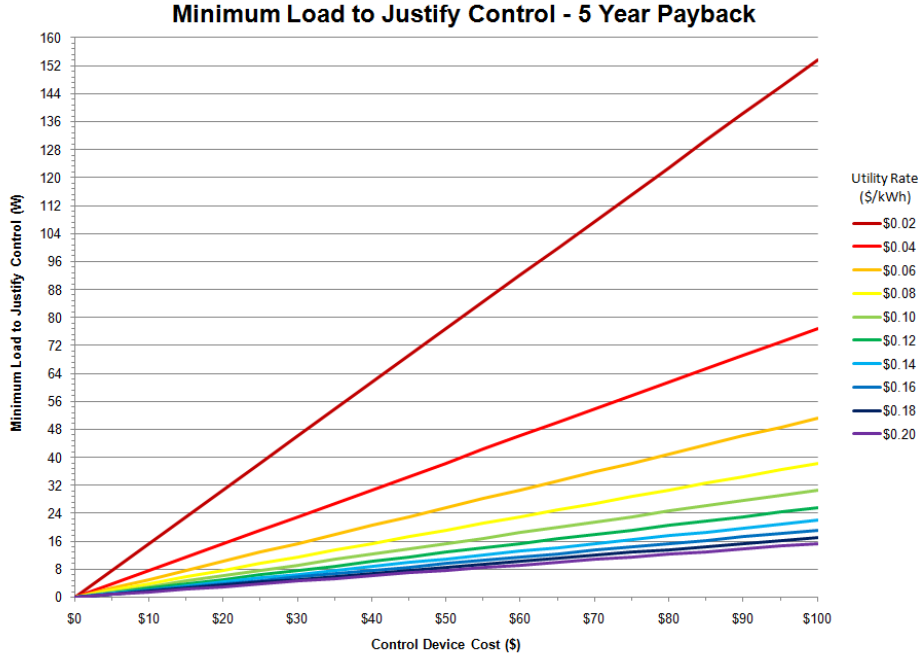

Figure E–4 Minimum load that can be cost-effectively controlled by a control device – 5-year payback

(Credit: Chad Lobato/NREL)

E.5 Ten-Year Payback Period

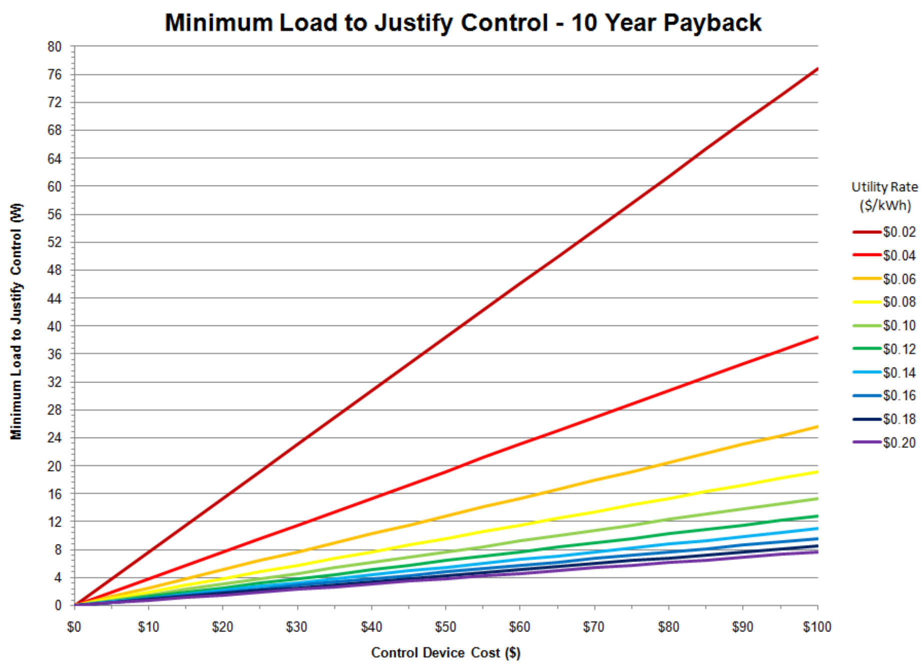

Figure E–5 Minimum load that can be cost-effectively controlled by a control device – 10-year payback

(Credit: Chad Lobato/NREL)