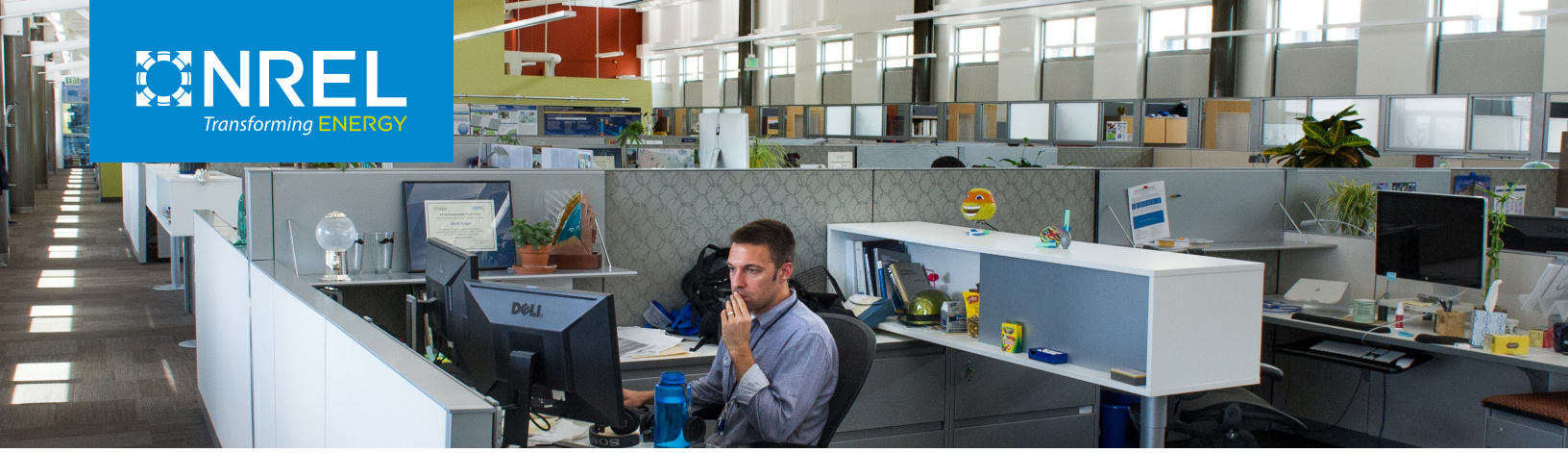


Photo by Dennis Schroeder, NREL 29518

Automatic Receptacle Controls:
What they are and why they should be commonplace in building energy codes

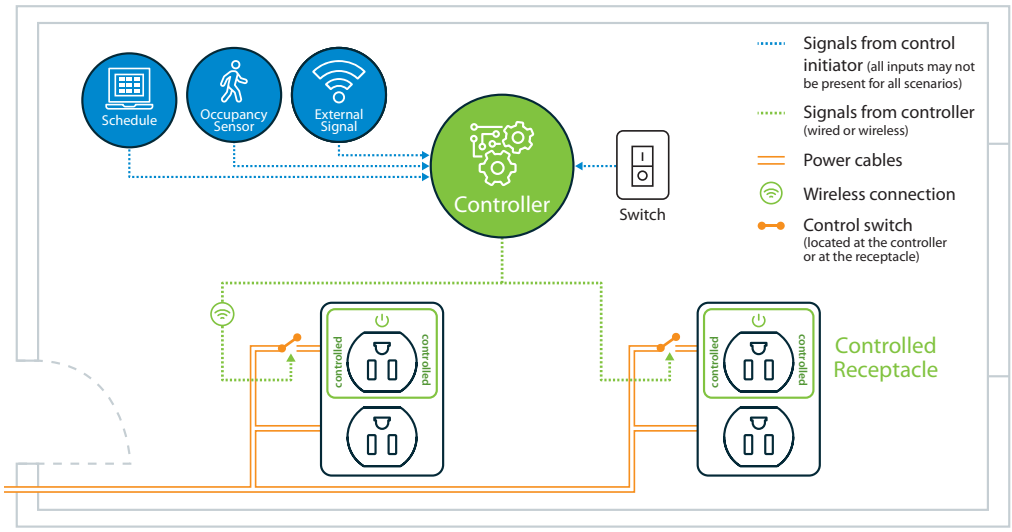
Introduction

Plug and process loads (PPLs) account for 47% of U.S. commercial building energy consumption (EIA 2020). As buildings become more energy efficient through other end uses, such as lighting and HVAC (heating, ventilating, and air conditioning), and as more electric devices are added to buildings, the PPL portion of building energy use will continue to grow and therefore should be addressed. PPLs, and specifically plug loads, have unique characteristics that can make it challenging to reduce their energy use. For instance, plug-in devices are often left on when not in use, drawing power. They also draw power while in standby mode, and some plug-in devices even continue to draw power when plugged in and turned off, referred to as vampire or parasitic loads. Automatic receptacle controls (ARCs), commonly referred to as plug load control, can help building owners and occupants reduce these plug loads. Therefore, a growing number of states and local jurisdictions are requiring ARCs as part of their commercial building energy codes.

What Are ARCs?

According to the U.S. National Electrical Code (NEC), Section 100, an outlet is a point in an electrical circuit from which current may be drawn. A receptacle is the contact device installed at the outlet and used to connect a plug. ARCs automatically turn off power to receptacles using signals from occupancy sensors, control schedules, or other building systems. They are best suited for plug-in devices that only need to be operational when the building is occupied. Examples of good plug-in device candidates for ARCs are:

- Displays/monitors
- Task/exam lights
- Space heaters
- Table fans
- Radios/speakers
- Printers
- Hot plates
- Coffee makers
- Televisions
- Exercise equipment.



How Do ARCs Work?

All ARCs provide an automatic means of controlling receptacles, but they vary in how they work. ARCs are available in single or duplex receptacle control configurations. Controllers such as plug load controllers, standalone controllers, and room controllers determine when to switch the receptacles on and off based on occupancy, schedule, remote control, or other factors. The controllers are connected to the receptacles either via a wired connection or wirelessly using a wireless communication protocol such as Wi-Fi (IEEE 802.11), Bluetooth, or Zigbee. Most ARCs allow users to override the receptacle shutoff, typically for up to two hours, via a manual switch or on the receptacle itself. ARCs save energy by automatic control with one of three methods:

- **Schedule-based** ARCs, also known as time or time-of-day ARCs, include controls that allow the user to set the days and times that a receptacle will be turned on and off. Scheduling is a good option for applications with predictable occupancy and for loads that must be on for business hours, such as printers and water coolers.
- **Occupancy-based** ARCs include controls that will turn a receptacle on or off based on a space's occupancy, determined via an occupancy sensor. After the space is unoccupied for a set amount of time, typically 20 minutes, the receptacles will shut off. Occupancy sensors used for lighting control in a space are often also used to operate ARCs in the space. Occupancy-based ARCs should be used for loads that can be turned off during operating hours and are particularly effective in applications where occupancy is variable, such as private offices and conference rooms.
- **System-based** ARCs receive a signal from another control system, such as a security or building automation system, that turns receptacles off after determining that the area is unoccupied for a certain amount of time, typically 20 minutes.

ARC Benefits and Savings

There are numerous benefits from ARC implementation. PPL controls turn off devices when they are not in use, reducing device energy consumption by up to 30%, which can often translate to whole-building energy savings of up to 6%–10% (Langner and Christensen 2018). A study conducted by the U.S. Department of Energy shows that performing a plug load inventory and implementing ARCs can reduce commercial building plug load energy use by 20%–50%. ARCs are just one type of PPL control strategy, but they can be particularly effective because they can mitigate occupant interference. For instance, a building occupant who comes into the office during non-business hours may need to override a scheduled off time for a receptacle. The occupant cannot remove the receptacle itself; rather, they can use an override function that turns power back on for two hours before it adheres back to the schedule. Because of these benefits, ARC provisions have been in some commercial building energy codes for over ten years. The electrical device market has responded with a variety of products that are available today.

Mitigating Concerns

Safety

- **Concern:** Use of ARCs could lead to unsafe use of extension cords and power strips to access controlled or uncontrolled receptacles. It's plausible that a building occupant could be dissatisfied with a controlled receptacle due to a control schedule or timer that is incompatible with their actual schedule and device power needs. Rather than proposing a plug load control timing change, the occupant may avoid using the controlled receptacle and use an extension cord or power strip plugged into an uncontrolled receptacle instead.
- **Mitigation Strategy:** Some energy codes have language regarding the required distance between the controlled and uncontrolled receptacles, which ensures that building occupants have nearby access to both.

Inspection and Enforcement

- **Concern:** As a newer code provision, building officials and inspectors may require enforcement guidance.
- **Mitigation Strategy:** Understanding the benefits of ARCs in buildings, knowing what to look for on construction documents, and recognizing the NEC required marking symbol will aid inspection and compliance enforcement. The National Electrical Manufacturers Association (NEMA) has developed a guidance document to assist building officials and inspectors (see References). Consistent, compliant installation will aid in proper utilization.

User Education

- **Concern:** There is a need to educate building owners and occupants on what ARCs are and how to use them, as they are only effective when properly used.
- **Mitigation Strategy:** Encourage building owners to educate occupants on how to identify an ARC (through a "controlled" receptacle marking), what should be plugged in to ARCs, and what is better suited for uncontrolled receptacles. Communication with occupants—via signage, emails, etc.—is key. NEMA has developed a guidance document for end users that provides this information.

Market Adoption

- **Concern:** ARCs are a lesser-known energy savings solution. They require some additional electrical design work and may require additional material and installation costs.
- **Mitigation Strategy:** Many design guides are available from ARC product manufacturers and from energy code compliance manuals. Including them in the adopted energy code will help drive their use and thereby increase energy savings.

What Can Be Done?

Plug loads are a notoriously challenging building end use to control. But as plug loads continue to make up a large portion of commercial building energy use, it's important to address them. Supporting and enacting commercial building energy codes with ARC provisions, coupled with educating building inspectors and end users, will accelerate plug load energy savings. As

ARCs become more commonplace through code requirements and market adoption, proper installation and utilization should continue to improve, increasing energy savings.

Energy Codes With ARC Provisions

Several states and jurisdictions are starting to adopt commercial building energy codes with ARC provisions for new constructions and major alterations. The most common ones are the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 90.1, California Title 24, and the 2021 International Energy Conservation Code (IECC). The ARC segments of these codes are relatively similar. Note that codes are updated periodically. The summaries below are code excerpts that were pulled in 2022. Readers are encouraged to access and read the full versions of the most up-to-date codes.

- **ASHRAE 90.1 – 2010 and newer:** At least 50% of all 125 V, 15- and 20-amp receptacles in all private offices, conference rooms, break rooms, copy rooms, classrooms, and individual workstations and at least 25% of branch circuit feeders installed for modular furniture not shown on the construction documents must be automatically controlled. All controlled receptacles must be permanently marked to visually differentiate them from uncontrolled receptacles. Plug-in strips and devices cannot be used for compliance. Acceptable compliance methods are:
  - Scheduled basis using a time-of-day operated control device with override feature for up to 2 hours
  - An occupancy sensor that will turn receptacles off within 20 minutes of all occupants leaving a space
  - Automated signal from another control or alarm system that can turn receptacles off within 20 minutes after determining an area is unoccupied.
- **California Title 24, Part 6 – 2013 and newer:** Requires at least one 15- and 20-ampere 120-V AC controlled receptacle, or a split wired receptacle with at least one controlled and one uncontrolled receptacle, to be installed within 6 feet of each uncontrolled receptacle for office areas, lobbies, conference rooms, kitchen areas in office spaces, and copy rooms. For hotel and motel guest rooms, install controlled receptacles for at least half of 120-V receptacles in each guest room. Controlled receptacles must have a permanent marking to differentiate them from uncontrolled receptacles. Plug-in strips and devices cannot be used for compliance.
  - Electric circuits serving controlled receptacles must have automatic shutoff controls such as occupancy sensors or an automatic time switch
  - Automatic time switch control must have an override control that allows the receptacle to remain ON for no more than 2 hours
  - Hotel and motel guest rooms require at least 50% of receptacles to be auto off via an occupancy sensor, captive key switch, or automatic control so they are off within 30 minutes of vacancy
  - Included in California Title 24, Part 6 – 2022: Effective January 1, 2023, controlled receptacles in buildings must be capable of automatically turning off all loads connected to the receptacle in response to a demand response (DR) signal. Exceptions for buildings not required to have DR lighting controls and for spaces where a regulation does not permit the receptacles to be automatically controlled.
- **2021 IECC:** Split controlled receptacles shall be provided with the top receptacle controlled, or a controlled receptacle shall be located within 12 inches of each uncontrolled receptacle. Plug-in devices do not comply. All controlled receptacles shall be permanently marked. Compliance methods include:
  - Time-of-day operated control device that can be programmed separately for each day of the week. Control device shall be configured to provide an independent schedule for each portion of the building of not more than 5,000 ft^2 and not more than one floor. Occupant can manually override an area for not more than 2 hours
  - Occupant sensor control that shall turn off receptacles within 20 minutes of all occupants leaving a space
  - Automated signal from another control or alarm system that can turn off receptacles within 20 minutes after determining area is unoccupied.

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