Photo by Joshua Bauer, NREL 61774

Smart Outlets: Wireless Meter and Control Systems for Plug and Process Loads

What are smart outlets?

Smart outlets control the flow of power to devices plugged into them and measure their energy use. These outlets collect control and energy data, which are then sent wirelessly, often via an intermediate gateway, to a cloud database or the building's energy management system (EMS). Often, data can be accessed via an online dashboard or smartphone application, allowing the user to turn power to plug-in devices on or off based on a schedule established in the dashboard or application. Additionally, some smart outlet systems use machine learning algorithms that can predict schedules, while others can apply controls based on occupancy sensor data. There are buttons built directly into smart outlets that allow the in-room user to instantaneously override the control and turn on power delivery through the outlet.

Smart outlet systems can also be connected to lighting and heating, ventilating, and air-conditioning systems through an energy management information system (EMIS) platform or advanced lighting controls. This interoperability allows building system energy use to be optimized by leveraging sensor data and building schedules, improving overall operation and efficiency.

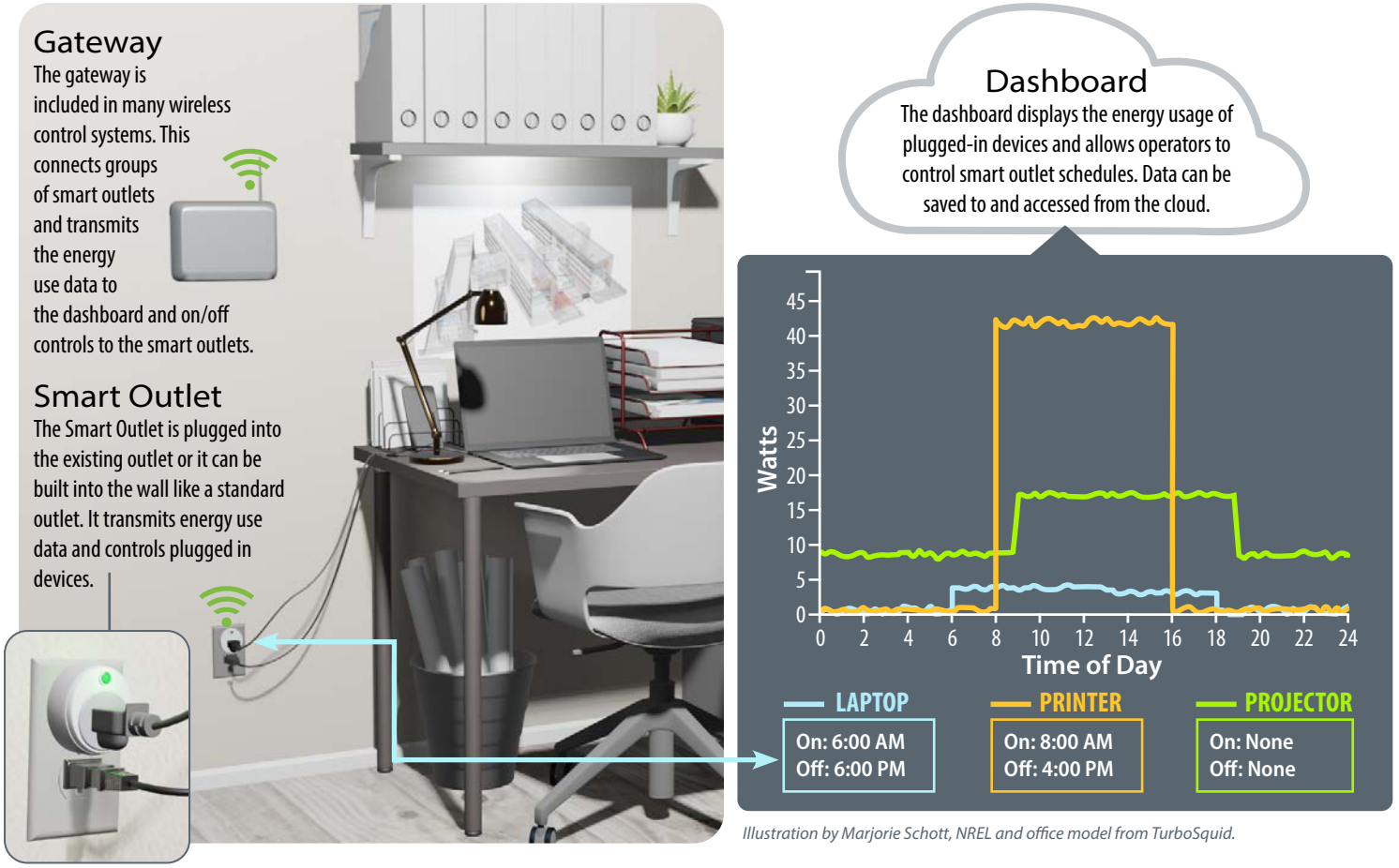

Illustration by Marjorie Schott, NREL and office model from TurboSquid.

Why use smart outlets?

Plug and process loads (PPLs) can account for up to 47% of commercial building energy use (EIA 2020). Smart outlet systems provide an opportunity to reduce building energy use and utility costs when deployed and managed properly.

- PPL metering can help identify opportunities for new control strategies by revealing the usage patterns of specific devices that consume large amounts of energy.
- PPL metering, paired with accessible dashboards, can increase occupant awareness of energy use and create even larger savings.
- PPL controls turn off devices when they are not in use, reducing device energy consumption by up to 30% and which can often translate to whole-building energy savings of up to 6%–10% (Langner and Christensen 2018).
- PPL controls can often be managed remotely, a major benefit when a building is unexpectedly vacated (e.g., during the COVID-19 pandemic).

In addition, smart outlet systems offer nonenergy benefits. A continuous flow of plug load data can allow for improved asset management, greater insight into occupant needs, and enhanced space optimization. The data provide a better understanding of how the building is being used and which locations in the building are used the most. Device energy use data can also shed light on devices that may need repairs, replacement, or removal. For instance, data might indicate that one printer is not being used, which could support the business case for removing that printer.

How do we use smart outlets?

Assess the Building

Before investing in smart outlets, and to streamline the system set-up, it is important to first understand the building's characteristics, operation and performance needs, and goals for implementing a wireless meter and control system.

Perform a Plug and Process Load Inventory

The **PPL Champion**, designated on-site staff, or vendor walks through the building to inventory PPLs and document their characteristics, which may include age, location, wattage, use schedule, and the purpose the device serves for occupants. An example of the information to be collected can be found on the inventory page of the NREL PPL reduction workbook for office buildings.

Create a Classification Strategy

A clear, well-documented device and outlet location classification strategy is critical to properly maintain smart outlet systems, enable effective analysis, and ensure system continuity. The classification strategy is independent of whichever smart outlet system you select. It should follow a straightforward hierarchy so that devices of a certain type naturally fall into one common category. See Figure 1 for an example of classifying computers in a building.

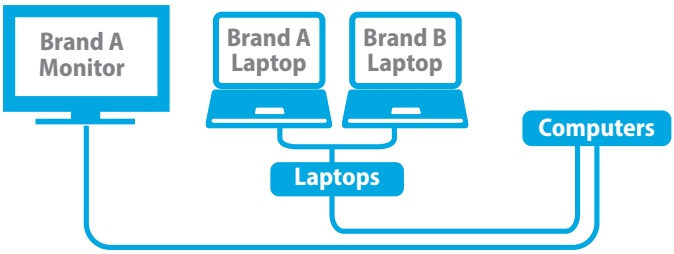

Figure 1. *An example hierarchy in the classification system for computers*

Similarly, projectors and speakers can be rolled into a larger category of audiovisual equipment or coffee makers and toasters can be rolled into a category of small kitchen equipment. This way, data aggregation and analysis can occur at whatever level is appropriate.

The label given to the device should establish the device type and location (e.g., Laptop1_BuildingA_Floor1). This makes the system easier to understand and maintain and allows for data analysis by device type or location.

Develop a Control Strategy

The control strategy should include a plan to identify and address devices that waste energy. Use the metering and control functions of the smart outlets to collect energy use data, identify devices that use excessive energy, and apply controls.

Metering

Metering tracks device energy consumption and creates greater visibility on how devices are used. Metering will identify:

- Devices that are left on during unoccupied hours
- Devices that unexpectedly consume a large amount of energy
- Devices with irregular load profiles.

Analyzing the metered data can provide insight on which devices to control. Devices that are consuming energy at unexpected hours and in unusual quantities may be good prospects for control. The meter data can show when a device is acting irregularly, potentially indicating that it

needs to be replaced. Some devices should be metered to understand device health, but do not need to be controlled. For instance, you may consider using a smart outlet for a refrigerator to understand its energy use and device health, but you would not want to control it by turning it on and off at a scheduled time.

Controlling Plug and Process Loads

The control functionality of the smart outlet can be used to capture energy savings in devices that are wasting energy. Before controlling each device, ask the following questions; if the answer to a question is "yes," avoid controlling that device.

- Is it unsafe for the device to be powered off by unplugging it?
- Is there a risk of data loss?
- Would controlling the device significantly inconvenience or disturb occupants?

Some examples of common devices that are controlled include laptop charging carts, monitors, audio visual equipment, copiers, and space heaters. Examples of common devices that are not typically controlled include data centers and refrigerators. Controls can be overridden at the outlet, so users can turn on controlled outlets at any time.

How do we procure smart outlets?

Once there is a clear understanding of control system goals and building needs, it is time to procure the smart outlet system. Smart outlets are becoming more readily available in the market and there are several options available. The considerations below are helpful for determining if a vendor's system is a good fit for a specific building and its occupants.

- **Outlet types**
  - Outlets with tamper-proof components (e.g., tamper-proof screws)
  - Plug-in smart outlets: Plug-and-play devices that have minimal installation requirements and can be moved easily, but also carry the risk of removal by occupants
  - Wall-mounted smart outlet: Replaces the standard outlet and requires a more complicated, hard-wired installation, but is less likely to be removed by occupants. Also effective for meeting the most recent ASHRAE standards (ASHRAE 2019) on PPL controls.
- **Software (how to receive and access data)**
  - Application programming interface/cloud platform
  - Internet of things connectivity
  - Cybersecurity protocols
  - Potential for integration with the EMS
  - Dashboard interface (e.g., web-based dashboard, mobile options, data organization).
- **Artificial intelligence, including smart outlets that use machine learning to automatically apply controls based on usage patterns**
- **Protection (prevent negative effects on devices), such as data storage during power outages**
- **Range and capacity of smart outlet network**
- **Demand response capability**
- **Smart outlet to database communication protocol (e.g., wireless fidelity (Wi-Fi), Zigbee, Z-Wave, or Bluetooth).**

How do we maintain the benefits of smart outlets?

Plug and Process Load Champion

Have a dedicated team member (referred to as the PPL champion) to:

- Manage the system
- Facilitate education about the system for occupants and staff
- Ensure that new occupants are educated.

Occupant Education

Make all staff aware of:

- What the technology is
- How it works
- Who to contact with questions or issues
- How to reset, adjust, and safely override the controls.

Occupant Engagement

Regular communication with building occupants is key! Positive messaging to occupants about how everyone contributes to the energy and cost savings goals fosters an understanding of personal responsibility. Education and engagement can prevent employees from unplugging the control system (Langner and Kandt 2019). Some employee awareness strategies include:

- Training
- Competitions among employees
- Signage, including stickers on outlets and plugs
- Regular email blasts
- Tenant guides (monthly tenant meetings to review plug load data is recommended) (Chang et al. 2014).

Data Analysis and Monitoring

Monitor the dashboard frequently to identify potential issues and capitalize on savings opportunities. For instance, an irregular device usage pattern could indicate a need to adjust the device's control schedule or even replace the device.

Please reach out to the **NREL PPL team** (ppl@nrel.gov) with questions or to request technical assistance.

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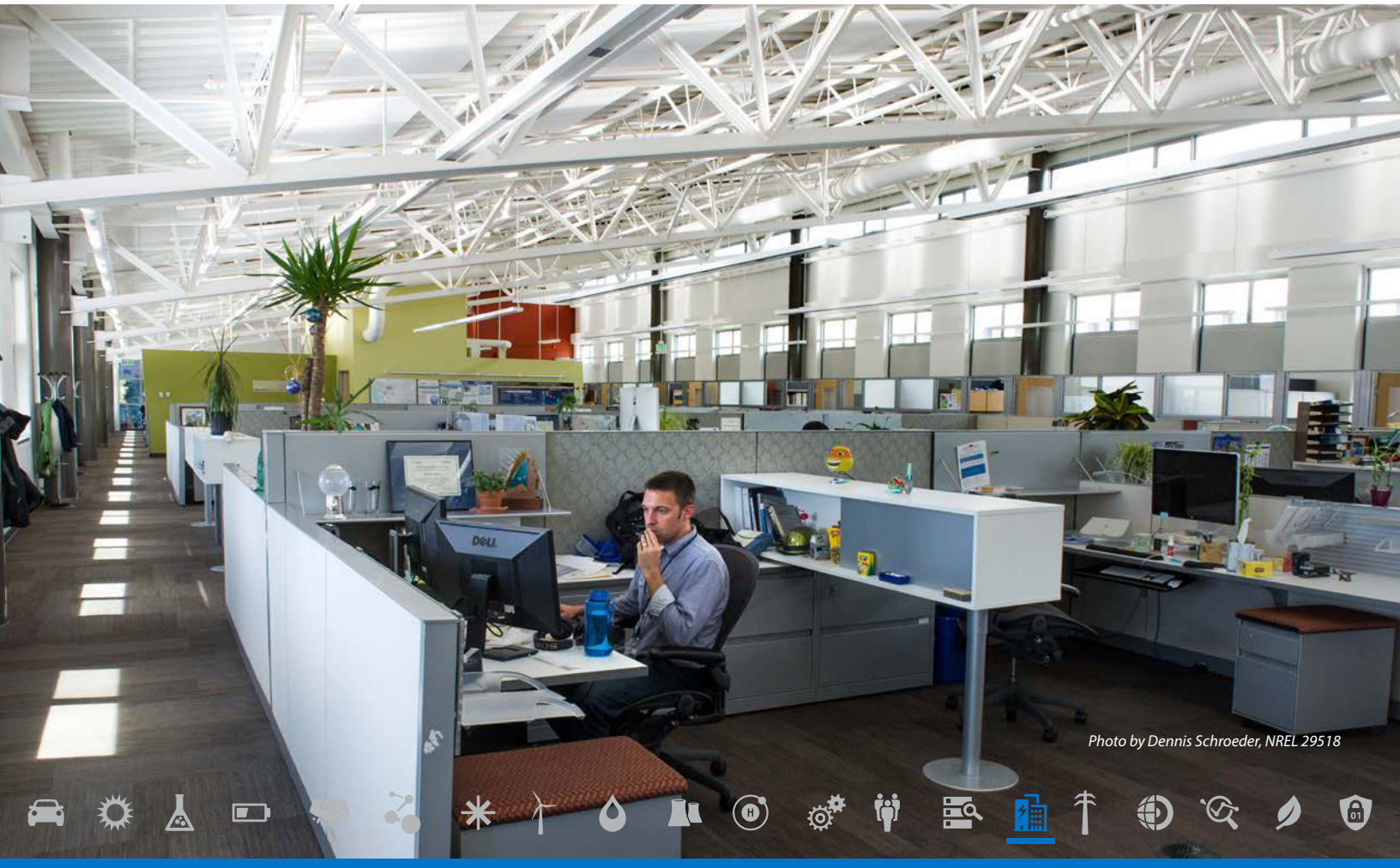

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NREL/FS-5500-77971 • March 2021