Office Building Plug Load Disaggregation

BETTER BUILDINGS ALLIANCE

Background

Plug loads account for a significant and growing portion of the energy consumed in commercial buildings, but they are one of the most difficult end uses to manage. Typically, building owners and managers do not have effective methods for monitoring plug load energy consumption. Sometimes plug loads are wired to a dedicated circuit, such that they can be metered in aggregate at the panel level. While this is helpful for evaluating plug load energy consumption at a building level, to truly understand how and when specific types of devices are consuming energy, metering must be done at the device level.

Today, smart plugs can meter and control devices and wirelessly report energy consumption to a central plug load management system. Smart plugs offer the potential for full building granular plug load monitoring. However, with thousands of devices in today's large buildings, individually monitoring every plug load becomes a nontrivial task. Researchers at the National Renewable Energy Laboratory (NREL) have attempted to address this issue by proposing a method for combining a limited amount of smart plug metering with a device inventory to develop a disaggregated breakdown of device-level power consumption in a zero energy office building.[1]

Disaggregation Study

Three months of power data were collected from 118 devices (15 types) in NREL's Research Support Facility (RSF) using Intellisocket smart plugs from Ibis Networks. An inventory of the devices in the RSF B Wing East was also conducted and used to estimate the number of devices of each type in the wing. Scaling the power consumption data by the estimated number of devices allowed the researchers to develop a disaggregated plug load profile for the wing. The plug loads in each wing of the RSF are wired to individual submeters so the researchers could compare the disaggregated model to the wing's measured aggregate plug loads. They found the disaggregated model's shape was similar to that of the plug load submeter, but the magnitude of the model was less than the submeter, indicating there were likely devices contributing to the submeter that were not captured by the model.

Figure 1. NREL's Research Support Facility. Image courtesy of Dennis Schroeder.

KEY TAKEAWAYS

- Taking a device inventory can lead to a better understanding of the variety and quantity of devices in a building.
- Combining a device inventory with a limited metering effort can reveal a building's disaggregated plug load profile and identify devices using more energy than expected.
- Disaggregation enables comparison of device consumption during occupied and unoccupied hours for better targeted controls and energy efficiency upgrades.
- The devices in a building evolve over time and plug load management strategies must evolve to meet these changes.

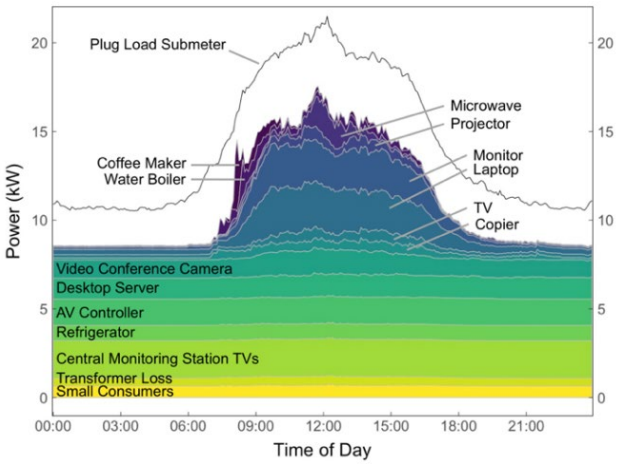

Figure 2. Disaggregated plug load breakdown for an average workday in the B Wing East.

[1] These findings were published in: Doherty, B. & Trenbath, K. (2019). Device-level plug load disaggregation in a zero energy office building and opportunities for energy savings. *Energy and Buildings*, 203, 109480.

Findings & Insights

The disaggregated plug load model (Fig 2) revealed new insights, including:

- **Laptops and monitors account for more than 20% of the daytime load**, but only a small portion of the evening load.
- **Occupant preference can significantly affect plug load profile shape**. The B Wing East has a midday spike to microwaves during lunch, while other studies find midday dips in buildings where occupants typically leave for lunch.
- Audiovisual **(AV) controllers and central monitoring station (CMS) TVs (on 24/7 for security) together contribute, on average, more than 3.5 kW to the baseload.**

Occupied and Unoccupied Loads

The device-level power data can be divided by occupied times and unoccupied times to better identify opportunities for energy savings (Fig 4).

- **Video conference cameras, desktop servers, AV controllers and CMS TVs make up a larger portion of the unoccupied load** than the occupied load.
- **The unoccupied load could be reduced by 25%** by adding controls to only 13 devices and shutting them off during unoccupied times. These devices included AV controllers, video conference cameras, and copiers.

Capturing Device Usage Diversity

For devices with load profiles that are dependent on usage, it is important to meter enough instances of these devices to capture their usage diversity. The morning spike due to the coffee makers in Fig 2 is a result of metering only one coffee maker instance and not capturing the usage diversity across the devices in the wing.

Device Load Profile Comparison

Collecting device-level power consumption data allows for comparison of device load profiles. Fig 3 demonstrates that the laptops and monitors are most strongly correlated with each other and with the plug load submeter. The coffee makers, water boilers, and microwaves are also positively correlated as they tend to be used in the morning and at lunchtime.

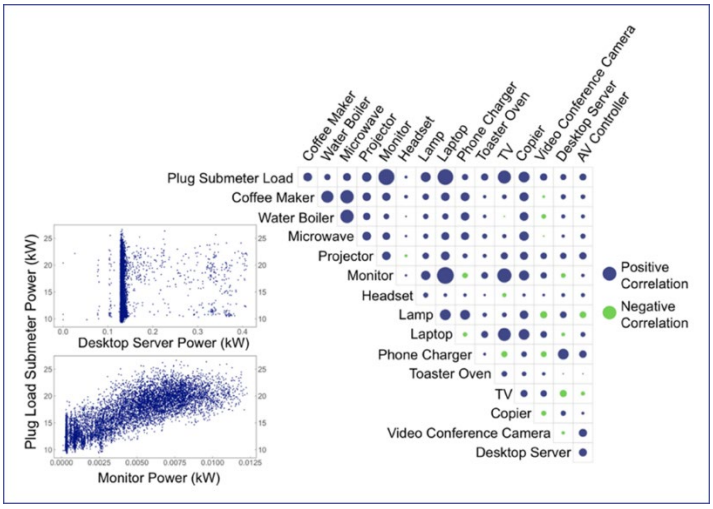

Figure 3. (Left) Scatterplots demonstrating the relationship between the plug load submeter, desktop server, and monitors. (Right) Graphic of Spearman rank correlation coefficients. Larger circles indicate stronger correlation.

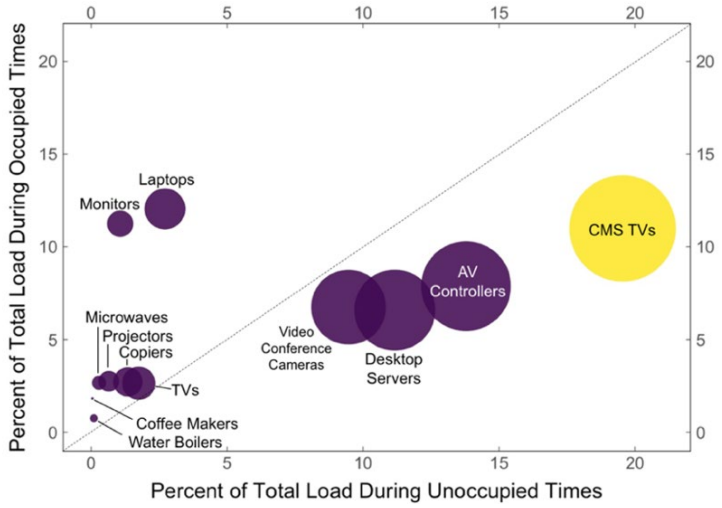

Figure 4. Mean power consumption as a percentage of the mean total plug load power in the B Wing East during occupied times (9 a.m. to 5 p.m.) and unoccupied times (9 p.m. to 5 a.m.). Purple indicates metered data and yellow indicates estimated data.

Conclusion

This study demonstrated that a device inventory and a limited device-level metering effort can produce a disaggregated plug load breakdown, uncovering energy savings opportunities. This study is limited to the RSF, however, and should be validated in other buildings to see if the method is generally effective.