How Much Energy Do MELs Really Consume? Why This Answer is So Hard to Get: Results from Metering a Sample of Buildings

James Dirks and Emily Rauch, Pacific Northwest National Laboratory

ABSTRACT

Miscellaneous electric loads (MELs) represent a large and growing segment of both commercial and residential energy demand. The Energy Information Administration (EIA) estimates that energy consumption of miscellaneous loads will increase nearly 50% between 2012 and 2035 with an energy intensity increase of nearly 20%. While MELs are small individually, they are so numerous that together they comprise significant power demand. The current magnitude of miscellaneous loads is not empirically known; EIA estimates it is currently 50% of commercial-sector primary energy consumption (Annual Energy Outlook, 2012). If estimates are correct, MELs will represent the single biggest impediment to the implementation of highly energy efficient buildings. Information on the actual energy use, common definitions, and trends in MELs is limited, hampering efforts toward developing technology, infrastructure, and policy solutions for reductions.

A study was initiated in 2009 with the goal of developing a proof of concept for metering, monitoring, and analyzing commercial MELs in a modest number of buildings. Efforts included capturing consumption information both by device and in total using a combination of circuit level and device level metering. The resulting analysis confirmed anecdotal evidence that MELs can consume significantly more energy than estimated, and also revealed unexpected results including variations in mode consumption patterns and seasonal variation. This paper highlights the challenges to evaluating MELs and their consumption patterns both at the building level and overall in the commercial sector.

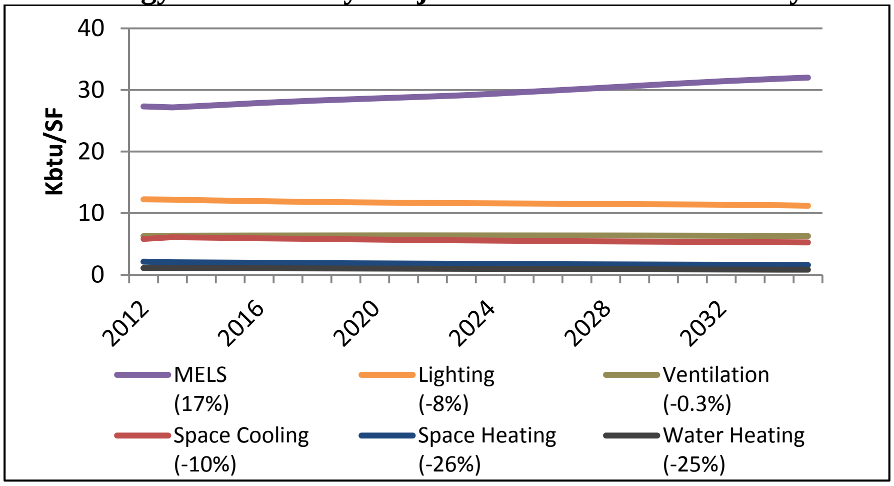
Background

Understanding the magnitude and characteristics of miscellaneous electric loads (MELs) in commercial buildings is a complicated quest. The amount of information in the literature is scarce while the estimates of growth by the Energy Information Administration (EIA) are significant. Miscellaneous loads include anything in the commercial building sector not considered a main building load (heating, cooling, lighting and water heating). The Annual Energy Outlook (AEO) estimates that energy consumption of miscellaneous loads will increase nearly 50% between 2012 and 2035. These AEO estimates are used in a multitude of investment decisions including power plant construction planning nationwide.

For purchased electricity, the miscellaneous load is projected to increase 47% in magnitude from 2012 to 2035, growing from 50% to 56 % of the total US electricity load in 2035. Accordingly, the MEL intensity is projected to increase 17% from 27 kBtu/sf to 32 kBtu/sf in 2035 while all of the other end uses are projected to show an energy use intensity decrease (see

Figure 1 below).

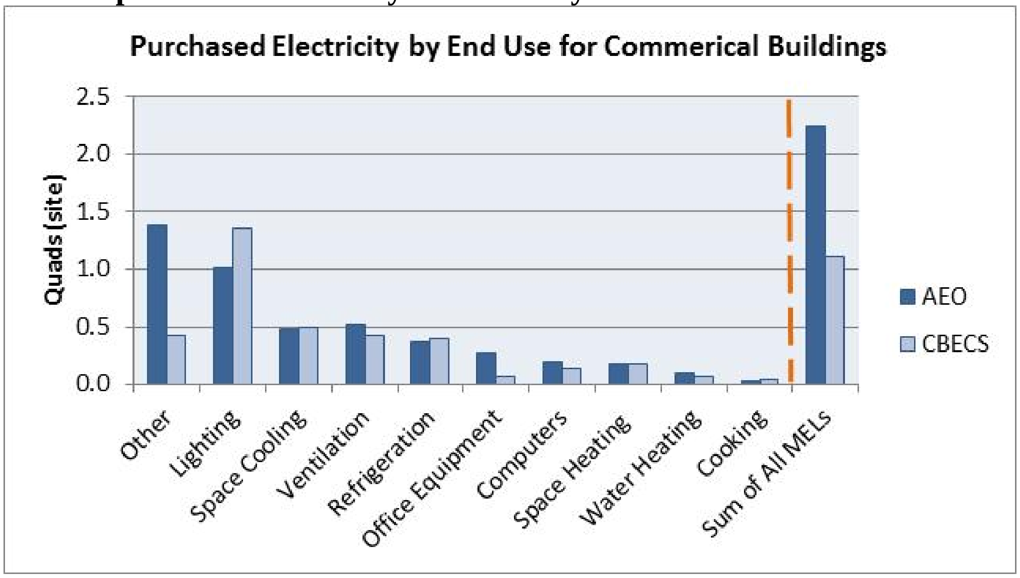
Figure 1. AEO Energy Use Intensity Projection from 2012 to 2035 by End Use



Source: DOE AEO 2012 Tab 5

Another commonly referenced data source for end use information is the Construction Building Energy Consumption Survey (CBECS) from 2003. CBECS derives the end use estimates based on statistical regression from utility bills of approximately 5,000 buildings, which breaks up the end uses in different building types (KEMA, 2008). Figure 2 compares the end use estimates from AEO and CBECs and summarized the loads that fall into MELs category at the right. The aggregation of Other, Refrigeration, Computers, Office Equipment, and Cooking make up the “Sum of All MELS” category. The “Other” categories have the largest variance between AEO and CBECs which is based on the methodologies and boundaries for analysis.

Figure 2. Comparison of Electricity Estimates by End use for AEO and CBECS



Source: EIA AEO 2012 Tab 5 and CBECS 2003 Table E4a

The other category is a type of catch all for energy use that was not directly associated with another use, and therefore the definitions of other are not explicitly defined. In AEO, the other uses category includes service station equipment, ATMs, telecommunications equipment and medical equipment. CBECS does not define other building uses in their tables. Because no one really knows what categories the “other” energy use should be in, the question is raised on whether the energy use is really a miscellaneous load inside the building, something outside of the building but connected, or whether the energy use is really just part of the other end uses but not estimated to be so.

There are few studies that have used metering to evaluate a handful of buildings or a certain category of MEL but are far from a comprehensive look at all building types and all MELs (Kaneda et al, Roberson et al, Roth et al) . A recent report by TIAX, commissioned by the US Department of Energy (DOE) in 2010 used CBECS, metering studies, and manufacturer estimates to estimate nation-wide loads from a select list of MELs (McKenny et al). However, without actual energy consumption data for different devices, in different building types, in different parts of the US, these results still yield high levels of uncertainty.

At the end of 2009 the first phase of a new project was launched by DOE to examination of MELs and the methodologies for metering and evaluating loads. This was a multi-laboratory effort by Lawrence Berkeley National Lab, the National Renewable Energy Laboratory, Oakridge National Laboratory and the Pacific Northwest National Laboratory (PNNL) which looked at 9 building types in different regions of the US. The metering activities discussed below are largely resulting from this effort (Brown et al).

What is a MEL?

How a MEL is defined can vary greatly depending on the situation, which can muddle the discussion around what the magnitude is and the possible solution set. The word “miscellaneous” is by definition a catch all for items not in a distinct category, and the letter “E” in the acronym is sometimes defined as energy, electronic, or electric. Alternatively, the term “plug load” is used instead to set the boundary around anything plugged in to an electrical outlet. The boundary widens when evaluating equipment that may be served off of a building meter but not commonly thought of as a “building load”. For example AEO’s other category includes miscellaneous uses, such as service station equipment, automated teller machines, telecommunications equipment, and medical equipment. The TIAX study defined commercial miscellaneous electric loads (C-MELs) as all commercial electric loads *except* those related to heating, ventilation, cooling, water heating, and lighting (i.e., main loads).

Another way these are described are as business process loads (BPLs), which tie the loads to the function of the business performed by the tenants in the space.

The definition used in the first phase of a DOE multi-lab study, and in this paper, is any electric load that is not in the main building service (HVAC, lighting, or water heating) as defined by the ANSI/ASHRAE/IESNA 90.1 building codes. This definition would categorize a space heater as a MEL because it was not included in the original design calculations even though it is technically providing heat to the space. It defines exterior lighting, extra task lighting, signage, or process lighting (a photo studio) a MEL because it is usually not included in design calculations of intensity. The list of types of MEL equipment is hundreds of lines long and when added differently designed equipment within those types the list grows exponentially.

Different Approaches to Metering MELs

As with any evaluation, the types and level of MELs metering that one does is dependent on the questions one is trying to answer. The questions being asked and the quality of the answers desired drives a number of requirements and ultimately the selection of the metering technology. For this study, several elements were evaluated including:

- Level of detail needed—what measurements need to be made (voltage, current, power factor, kWh, etc.), and how frequently do the measurements need to be made (hourly, every minute, second, sub-second)
- Length of metering activity—long term metering requires protection of the meters and economical methods of data collection
- Budget—sometimes thoroughness must be sacrificed because of budget constraints and metering acquisition and installation costs
- Circuitry configuration—if a circuit serves a single load then circuit level metering can be used rather than device level metering
- Variability of load—highly variable loads and loads with multiple operating states require longer metering periods
- Seasonality of load—accurate measurement of seasonal loads requires metering for 1 year or more.

For the purposes of this study we were attempting to gain insights into 3 fundamental questions; What fraction of total electricity consumption do MELs represent in different building types? What is the diurnal and seasonal variability of the MELs? What is the breakdown of MEL consumption by MEL category?

Given the questions and the nature of the loads we were metering, one time measurements and meters that simply accumulate a total consumption over the period of use were inappropriate. Hence, by necessity, we were compelled to do at least some device level metering. Where possible we did circuit level metering in lieu of or in addition to device level metering. Device level metering is generally more expensive as well as more intrusive in occupied spaces, therefore the first choice approach is to meter at the circuit. If we were only trying to answer the first 2 question and the circuit configuration was desirable we would have simply done circuit level metering without device level metering.

One final critical factor in the selection of metering technologies is simple practicality. Meters take many shapes and forms making them more or less conducive to different spaces. For example:

- When metering computer loads many meters are often required as is visible when looking at the power strip supplying the loads. A single computer could have 3 or more monitors, 2 or more sets of individually powered speaker sets, 1 or more printers, scanners, or other devices, and a CPU. The amount of available space for meters and data communications must be carefully considered.
- Public spaces have issues with device level meters disappearing as well as unintended reprogramming from curious “button pushers”.
- How willing the owner is to tolerate visible metering, even in non-public spaces, can also be an issue.

Metered Spaces and Approach Chosen

The multi-lab DOE study team selected different building types for MELs metering in order to better explore the opportunities and challenges with collecting device-level energy data in the field, two of the buildings which PNNL metered are described herein. For logistical, budgetary, and practical reasons, the PNNL portion of the team selected buildings on the PNNL campus. The following is a brief description of the spaces and buildings metered, which is not only important in determining the metering approach, but also when analyzing the resulting data.

- **Food Sales and Service.** The Bistro is approximately 3,000 sf and was built as a tenant space within a large laboratory building in 1997. The average food service building in CBECs is 5,600 square feet and operates at energy use intensity (EUI) of 258 kBtu/sf. The Bistro is open for breakfast and lunch (6:30am-2pm). The maximum occupancy for seating is 75 people and 3 people are on staff.
- **Warehouse and Storage.** The Shipping and Receiving Warehouse has six unique spaces within the building: receiving, shipping, janitorial storage, lunchroom, locker room, and offices. There is a high intensity CMELs per workstation and a large number of power strips. This 1960s, 1 story, 7,000 square feet facility operates on a standard 40 hour weekly schedule during the majority of the year; in August and September the building remains open for a 50 to 60 hour work week. The building houses an average of 33 employees. The average warehouse building in CBECs is 16,900 square feet and operates at an EUI of 45 kBtu/sf.

For this study, a mixture of circuit level and device level metering were chosen to gather data. The instances where only circuit level metering was required included: circuits with a single load, circuits with multiple identical loads operated in the same manner, and circuits serving multiple outlets in public spaces for which there were no permanently installed loads. Metering by circuit gave us the MEL totals by general area of the building. Device level metering was also installed to gather data on smaller equipment on the circuits. In some cases an aggregate approach to metering devices was used. When metering devices individually was deemed impractical, a power strip with multiple outlets was metered, or a number of devices on the circuit were metered and then subtracted from the total circuit meter value.

The circuit level metering equipment used was a 42 circuit system developed by Smart Solutions Group Inc. (www.smart-watt.com) and the second type was device level metering developed by Electronic Educational Devices Inc. (www.wattsupmeters.com). Both types of metering equipment devices were set up to operate using Wi-Fi and send the data to an internal server[1]. The WattsUP meters were configured to the .NET setting using somewhat complicated set of wireless repeaters and access points in the spaces. It is important to note that neither of these devices was specifically designed for the application of metering MELs in large quantities. While this did not lower the quality of the data received, this did cause challenges on the implementation side.

Interval data was collected at 5 minute increments from the circuit meters and 20 second increments from the device level meters. While this greatly added to the data storage

[1] Internal servers were used rather than the vendor's server due to internet security requirements at the facilities being metered.

requirements and analysis complexity, this type of interval also dramatically improved to the understanding of the energy consumption by device mode and occupant usage patterns. The data represented in the results section below was gathered over the first 6 to 12 month period.

What the Data Can Show – Results from Two Buildings

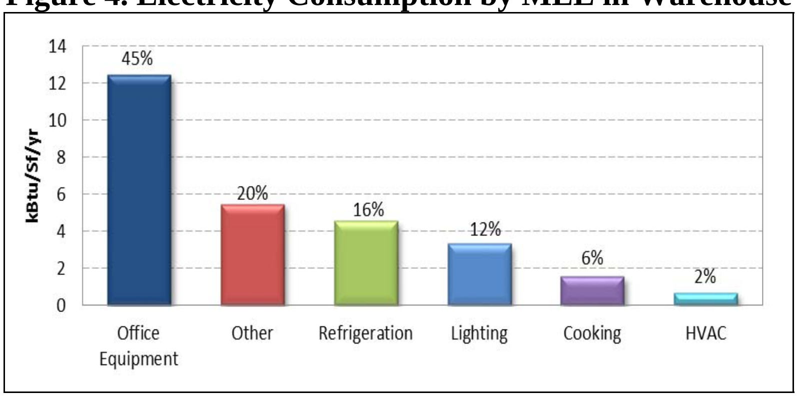
The cursory analysis of the data gathered at the device and circuit level from the food service and warehouse spaces shows a number of different insights into MEL patterns, profiles, and magnitudes. While some of the results were not surprising, many were different than anticipated and only lead to more research questions on specific devices, different building types and for the commercial sector as a whole.

Metering at the Circuit Level

Circuit level metering can provide a complete history of consumption over a long period of time with great detail. It is much less intrusive than device level metering, has a lower cost per point metered, the points are all collocated at the electrical panel which offers has much easier data collection and communication. In fact, in some instances it is a nearly perfect substitute for device level metering. With circuit level meter we are able to address the questions regarding what fraction of total electricity use is consumed by specific large MELs and what the aggregation of MEL consumption by MEL category was. Because of the way the circuitry was designed in the metered buildings, portions of the building are on different breakers and the non-MEL loads were on separate panels.

The following are some examples of the results of circuit level metering and some of the insights that can be drawn from them. Figure 3 presents the MEL consumption by MEL category in a shipping and receiving warehouse. Note that the heating is primarily served by natural gas roof top units; therefore the HVAC electricity load is a very low percentage of the total load. The warehouse is cooled in the summer but at a high set point.

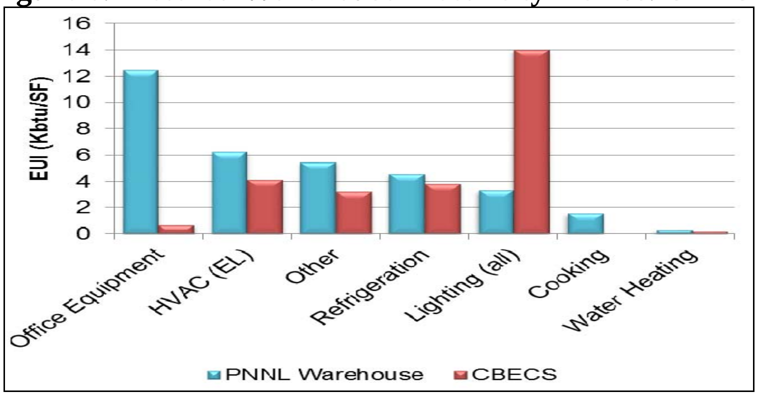
Figure 4. Electricity Consumption by MEL in Warehouse



Source: PNNL Warehouse Metering

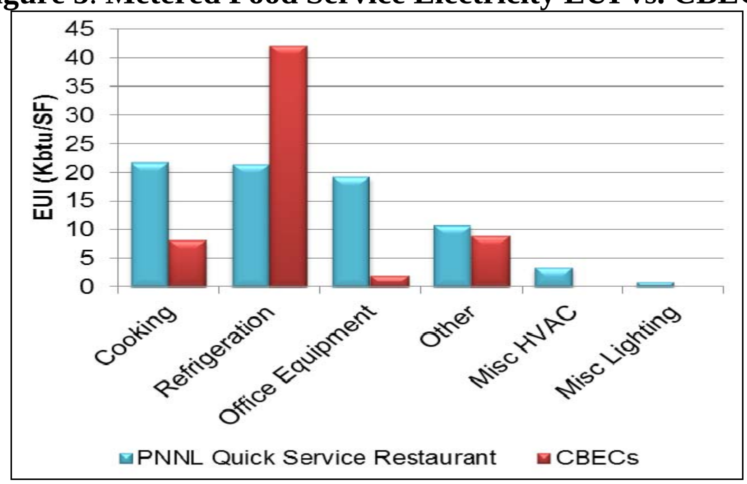
Figure 5 shows that the office equipment EUI in the metered warehouse was significantly higher and the lighting was significantly lower than CBECS estimates. Figure 5 shows that the cooking and office equipment loads in the Bistro were higher and refrigeration was lower than CBECS estimates.

Figure 6. Metered Warehouse Electricity EUI vs. CBECS



Source: PNNL Warehouse Metering and CBECS Table E4

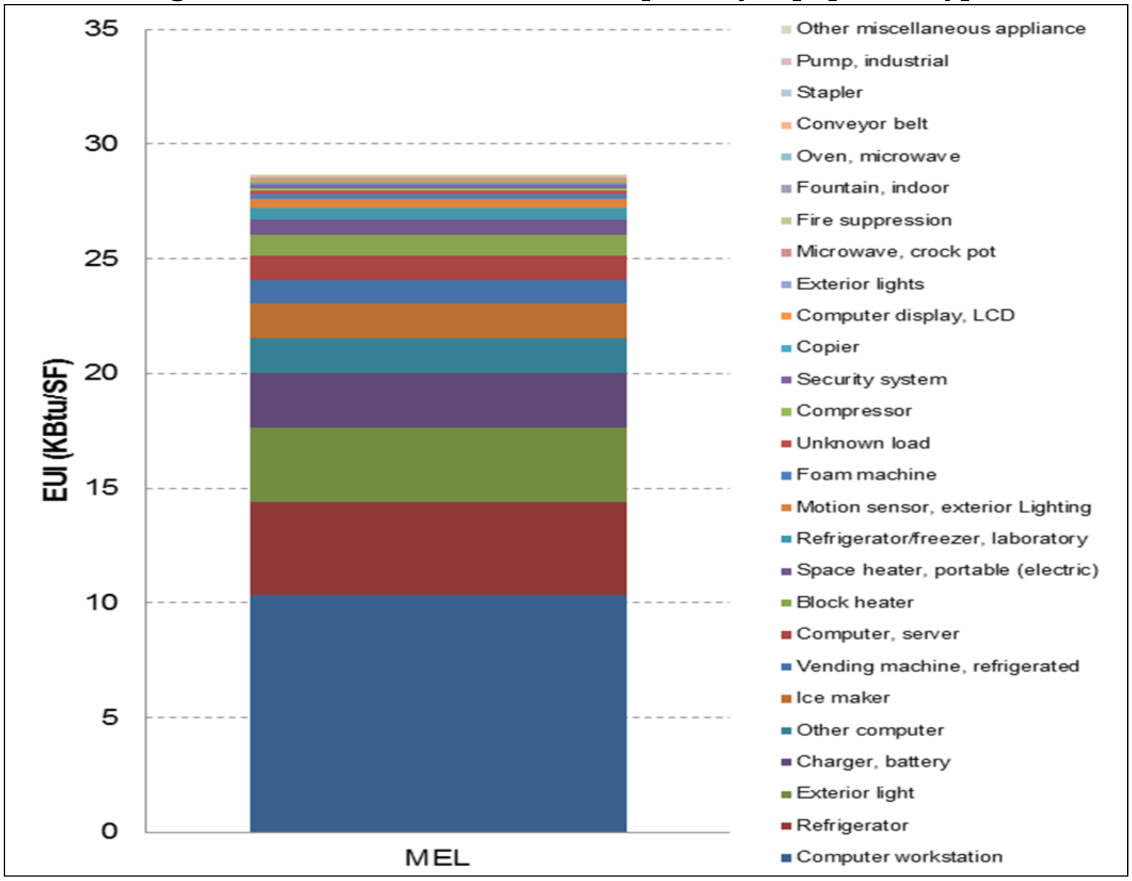
Figure 5. Metered Food Service Electricity EUI vs. CBECS



Source: PNNL Food Service Metering and CBECS Table E4

In Figure 6 a finer breakdown of the warehouse MELs is shown using a more detailed level of the taxonomy for the different devices. This was developed using both panel level and circuit level metering to get the resolution by device type. Some of these loads could not have been metered using an in-line device because of the rating of the equipment, while other loads had multiple devices on the same circuit therefore device level metering was needed. Note that computer workstations, refrigeration, and exterior lighting are the 3 largest loads.

Figure 6. Warehouse MELs Consumption by Equipment Type



Source: PNNL Warehouse Metering

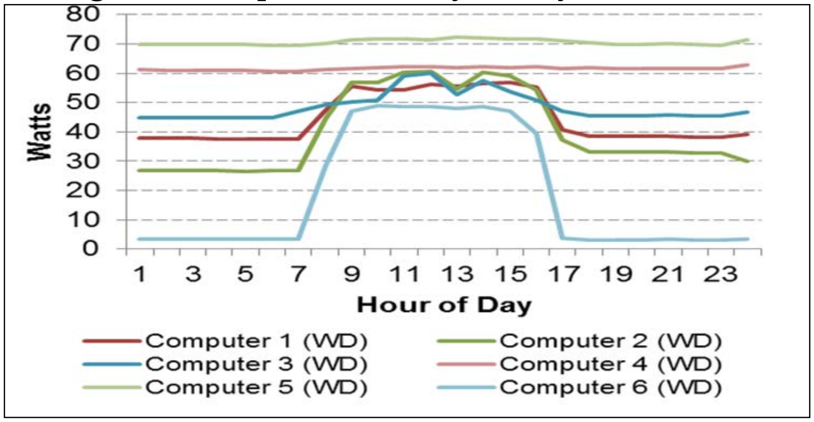
The four examples above show how circuit level metering can provide insights to the magnitude of MELs in a building. In some cases MELs consume more than expected in total, traditional building loads can consume more or less than expected, and certain types of MELs on their own can be significantly larger than traditional building loads such as lighting.

Metering at the Device Level

Device level metering can provide a complete history of consumption for specific devices over a long period of time with great detail. Following are several examples of the results of device level metering and some of the insights that can be drawn from them.
Figure 7 shows the weekday load profiles for 6 nominally "identical" computers in the same space. The users of the computers have the same official work schedule, 7am to 4pm, but the peak and standby mode magnitudes vary significantly. This demonstrates several benefits of device level metering:

- Wildly different consumption patterns can occur for nominally identical device—sampling could miss significant opportunities for energy savings and introduce significant error into estimates.
- One time measurements are not suitable for multimode devices

Figure 7. Computer Weekday Hourly Load Profile

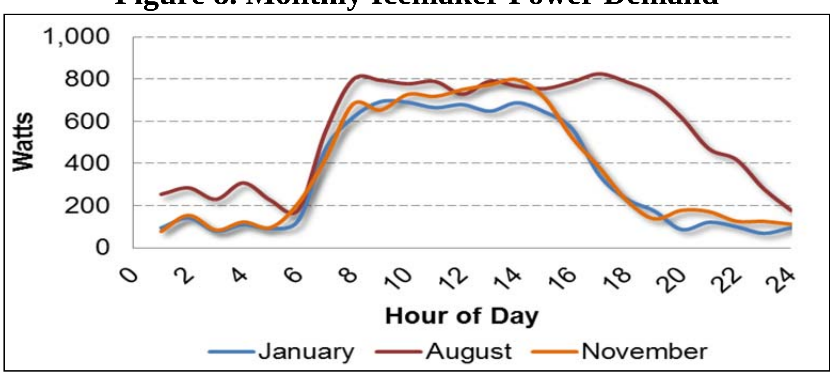


Source: PNNL Warehouse Metering

Figure 8 shows the average hourly load for 3 different months for an icemaker in the Bistro. The average profile for the month of August has a higher peak in the morning and stays in the active mode until 6pm, where the other months show a decreased demand after 4pm. The hours of Bistro operation stay the same in the summer, but the ambient temperature is set-back causing warmer morning and evening ambient temperatures. We presume that the higher ambient temperatures are the reason for the greater daytime and nighttime loads while the longer summertime active mode is due to increased ice consumption which requires a longer recovery period. The figure below demonstrates the following benefits of device level hourly metering:

- Some MEL loads are highly seasonal
- Seasonal differences impact amplitude of the consumption profile and also the shape

Figure 8. Monthly Icemaker Power Demand



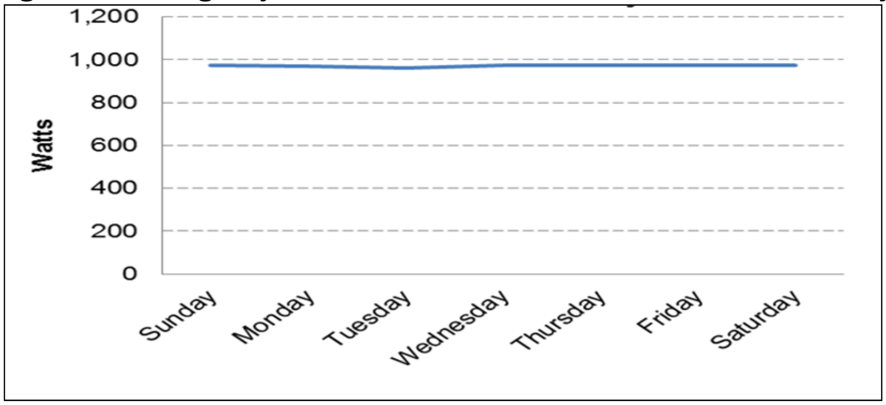
Source: PNNL Food Service Metering

Figure 9 shows the average hourly load for 1 week for a generator fuel heater; the lack of temperature control in the device causes the usage pattern to be seasonally invariant. This demonstrates the following benefits of device level hourly metering:

- Some loads have no hourly variation when one would expect one (e.g., if thermostatically controlled one would expect the heater to cycle on and off to maintain the desired fuel temperature)

- Some loads have no seasonal variation when one would expect one (e.g., if thermostatically controlled one would expect the heater load to vary based on the temperature in the unconditioned space which is highly dependent on outside temperature)

Figure 9. Emergency Generator Heater Load – 720 KWh Monthly

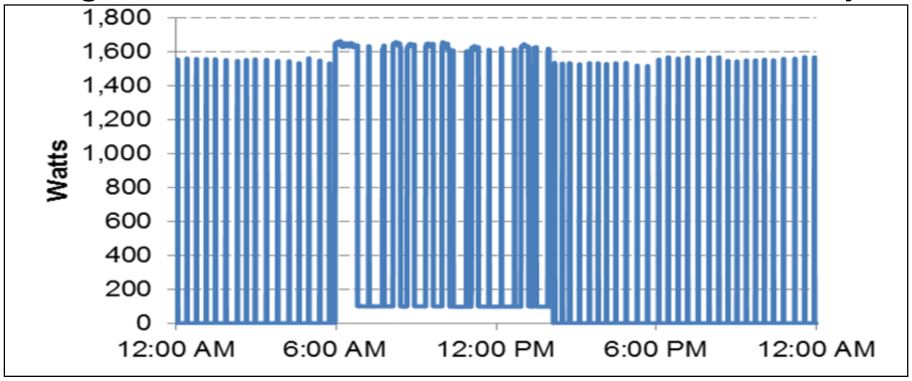


Source: PNNL Metering

Figure 10 shows the average hourly load for a 24 hour period for a quick service coffee maker. A clear increase in consumption occurs during the open hours of the Bistro, with a steady cycle profile during unoccupied hours. This demonstrates the following benefits of device level hourly metering:

- The initial morning brew cycles is clearly identifiable as the long "on" period near 6AM
- The keep warm plate energy (6AM to 2PM) is clearly identifiable by the step function increase in the load
- The standby load is large and unnecessary when coffee is not being brewed or expected to be brewed in the near future

Figure 10. Food Service Coffee Maker – 140 KWh Monthly



Source: PNNL Food Service Metering

The four examples above show how device level metering can provide insights into the operations of different type of equipment, with different users, with varying penetration within a building. More often than not "identical" loads are not identical, equipment has seasonal increases and decreases in consumption, equipment is not thermostatically controlled when it could be, and equipment in stand-by mode consumes more energy than anticipated. Several opportunities for load reduction through applying different energy management settings and installing new controls were identified but not covered in this paper.

Why is the MELs Consumption Answer So Hard to Get?

Traditionally, estimates of end use loads come from a mixture of utility metering data at the building level, paired with market penetration data for equipment sold. The HVAC, lighting water heating are disaggregated from the loads and then the remaining load is estimated to be refrigeration, cooking, office equipment, computers, and “other”. While the traditional end use estimates are based on decades of data collection, MELs estimates are based on little actual data collection.

If MELs actually represent 50% of commercial-sector primary energy consumption as EIA estimates and MELs are the only end use where intensity is projected to increase, why is this area not at the forefront of buildings research? Four theories, based on decades of experience in the buildings R&D field, are outlined below.

1. Because there is not a well-defined target, decision makers are reluctant to invest in MELs research. Clearly defined problems with identifiable solutions are more likely to get research funding.
    - Even the definition of MELs is ambiguous among those who work in the field.
    - MELs are not “sexy” and there is no single, clear objective.
    - The most important MELs vary by building type.
    - For many building types we cannot even identify the top 5 MELs.
2. It is often not clear what question or questions should be answered regarding MELs. Four common questions include:
    - What fraction of total energy consumption are MELs?
    - Is the fraction, or absolute amount, of consumption increasing or decreasing?
    - Are different categories of MELs growing at different rates?
    - What can be done to reduce the consumption? Do we really need to know the magnitude to the problem before we begin to try to reduce the consumption?
3. Methods for data collection and analysis are not well established (Cheung et al).
    - Does every MEL in a building have to be measured?
    - How large a sample is valid? Does it vary by type of MEL?
    - How long do you need to meter? Does it vary by type of MEL?
    - What is the best approach to analyzing large amounts of metered data?
4. The cost of MELs meter is significant compared to the amount of energy being measured.
    - Does each MEL need to be measured individually, or can lower cost circuit level metering be used to measure aggregated MELs of a similar type?
    - What can be done to lower the cost and reliability of MELs data collection?

- Can MELs be metered and controlled at the electrical outlet through the building automation system, or is a standalone system the best approach?

Based on this study and other metering studies we can begin to answer some of these questions and understand how this data can inform technology solutions to reduce MEL energy consumption and the importance of using actual metered data to frame the nation's energy reduction strategies in commercial buildings.

Conclusion

Collecting field data on miscellaneous loads in commercial buildings highlights the variability of usage patterns and magnitude of consumption by different devices. Without this level of data collection the buildings industry has to rely on calculations and statistical regressions to provide insights in to how this end use is contributing to commercial building loads. Definitively establishing the magnitude of all of the building end-use loads (heating, cooling, ventilation, lighting, water heating, and miscellaneous), their trends, and our ability to impact them is important for the proper allocation of research budgets and technology development.

Specifically in the MELs end use we need to know at some level what the significant MEL loads are, and if there are opportunities to reduce those loads or otherwise serve the need, before we can aggressively attempt to reduce loads in a reasonably cost effective manner. In order to the do this though, the cost of measurement must be reduced so that the necessary data can be collected in a cost effective manner. Individual MELs must be measured in sufficient number in actual application to determine their true nature and diversity. Developing a statistically significant sample is generally viewed as cost prohibitive; hence, the reliance on estimates, smaller than desirable sampling sizes, and shorter than optimal measurement periods.

While only on a single study basis, the data collected to date shows different consumption characteristics than what is estimated and a diversity of consumption patterns for "identical" devices that absent from the regression and calculation approaches. In order to develop a solution set that is based on real numbers versus estimates, some level of metering needs to happen in a statistically significant sample of buildings over time, otherwise MELs will continue be the single largest impediment to low energy buildings.

References

Brown RE, SM Lanzisera, JA Dirks, EM Rauch, LG Polese, M Sheppy, E Vineyard, and JL Rast. 2010. Monitoring and Characterization of Miscellaneous Energy and Business Process Loads: Demonstration of Field Methods in Diverse Commercial Environments (Interim Final Report).

Department of Energy. 2012. AEO2012 Early Release Report. http://www.eia.gov/forecasts/aeo/er/. Energy Information Administration (EIA).

Department of Energy. 2006. *2003 Commercial Buildings Energy Consumption Survey: Detailed Tables*. Washington, DC: Energy Information Administration.

Cheung, H.Y. Iris, Steven Lanzisera, Judy Lai, Richard Brown, Stephen Dawson-Haggerty, Jay Taneja, David Culler. 2010. *Detailed Energy Data Collection for Miscellaneous and Electronic Loads in a Commercial Office Building.* 2012 ACEEE Summer Study on Energy Efficiency in Buildings, Washington, D.C., ACEEE.

Kaneda, David, Jacobson, Brad, and Rumsey, Peter. 2010. *Plug Load Reduction: The Next Big Hurdle for Net Zero Energy Building Design.* 2010 ACEEE Summer Study on Energy Efficiency in Buildings, Washington, D.C., ACEEE.

KEMA. 2008. Energy End-Use Consumption Estimates for Commercial Buildings.

McKenney, Kurtis, Matthew Guernsey, Ratcharit Ponoum, and Jeff Rosenfeld. 2010. Commercial Miscellaneous Electric Loads: Energy Consumption Characterization and Savings Potential in 2008 by Building Type. http://zeroenergycbc.org/pdf/2010-05-26%20TIAX%20CMELs%20Final%20Report.pdf.Lexington, MA: TIAX LLC.

Roberson, Judy A., Carrie A. Webber, Marla C. McWhinney, Richard E. Brown, Margaret J. Pinckard, and John F. Busch. 2004. *After-hours Power Status of Office Equipment and Energy Use of Miscellaneous Plug-Load Equipment*. http://enduse.lbl.gov/Projects/OffEqpt.html. Berkeley, CA: Lawrence Berkeley National Laboratory.

Roth, Kurt, Gerald Larocque, and Jonathan Kleinman. 2004. *Energy Consumption by Office and Telecommunications Equipment in Commercial Buildings--Volume II: Energy Savings Potential*. TIAX Reference no. D0065-11.08. 2008. Cambridge, MA: Prepared by TIAX LLC for the U.S. Department of Energy.