

Home Energy Displays

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Energy consumption can vary dramatically among households, even when the households have similar physical characteristics. For example, a study carried out in the 1990s evaluated the energy consumption of 10 identical all-electric homes in Florida outfitted with the same appliances and equipment. Despite their similarities, the homes exhibited a large spread in energy consumption, with the most energy-intensive home consuming 2.6 times more energy than the least.¹

Clearly, occupant behavior has a major impact on building energy consumption, suggesting that interventions to modify occupant behavior could result in appreciable energy savings. Current utility billing practices greatly limit the feedback that most households receive on their energy consumption. That is, they only receive monthly utility bills that summarize their energy expenditures and consumption for the prior month. Kempton and Layne^{2,3} explain the pitfall of attempting to change behavior in this situation by analogy:

“Consider groceries in a hypothetical store totally without price marking, billed via a monthly statement.... How could grocery shoppers economize under such a billing regime?”

Unsurprisingly, residents find it challenging to understand how specific behaviors impact energy cost and consumption. This impedes households motivated to reduce their energy consumption from doing so. In particular, it is challenging to identify what devices and equipment consume the largest quantities of energy.⁴

Typically, information alone does not appear to be sufficient to achieve appreciable reductions in energy consumption, because relatively few people will act on the information. Specifically, people need a strong motivation to change, confidence that they can change, and feedback that changes they make are having an impact.^{3,5} As such, most successful approaches provide more frequent feedback, as well as specific feedback on specific behaviors.⁵

Home energy displays providing real-time feedback on energy consumption have the potential to enable residents to act to reduce energy consumption and address all three factors noted above. Specifically, they provide consumers information about the cost of the energy they consume (motivation to change), and the ability to rapidly see how changes in behavior alter energy expenditures and consumption.

Several home energy displays are commercially available.^{1,6,7,8} The information they present varies appreciably, as do the approaches used to measure electricity consumption* and communicate that information to the display. Most are relatively small, i.e., about the size of a two-plug outlet. Some are fully

portable (wireless), while others are semi-portable (plug-in) or fixed (hardwired).^{3,6,7} In addition, researchers are exploring displaying energy information via televisions and PCs.^{3,9}

In all cases, the home energy display system measures power draw from the electric meter or breaker box, often using a clip-on device transformer/transducer to measure current and, sometimes, voltage.^{6,7,†} The measured values are communicated to the in-home display via power-line carrier (PLC), a dedicated hard-wire connection, or wireless radio.^{6,7,10} In general, PLC and wireless devices are easier to install. Some newer systems are designed to work with meters and measure report values directly from the meter.^{6,8}

Typically, home energy displays can present basic information, such as real-time power draw (kW) and projected hourly electricity cost and electricity consumption (kWh) based on real-time power draw. Some can display additional information, such as daily electricity cost and consumption; electricity cost and consumption over the last 24 hours, the current month, and/or prior month; projected monthly electricity cost and consumption; monthly peak demand; greenhouse gas emissions; and outdoor temperature.^{3,6,7}

Prepayment systems, also known as pay-as-you-go systems,³ have displays and require users to purchase electricity using a smart card in advance of consuming energy. Consumers add additional value to their smart cards in stores and then swipe the card through in-home units that can display some or all of: quantity of energy remaining on the meter; current energy use rate (in dollar or kWh); dollar of energy used yesterday and last month; the current electric rate; and the smart card balance.^{3,11}

In addition, small-scale demonstrations of much more sophisticated home energy displays have been carried out. Typically, they provide much greater detail about electricity consumption, e.g., broken down by different end uses or circuits, and use richer display graphics.^{1,7,12,13}

In contrast, ambient approaches, also known as “calm technology,” provide qualitative—not quantitative—feedback on electricity consumption or electric demand. Such devices do not require direct attention, but effectively communicate information peripherally.⁶ For example, an energy orb that is green during periods of lower electric demand changes color in response to impending increases in electricity prices driven by

* Most home energy displays only show electricity consumption.³

† Measuring voltage enables measurement of actual power draw instead of apparent power draw, which ensures accuracy when measuring devices with lower power factors.

high electric demand.^{6,8} In another case, Electricité de France used a plug-in box that displays different colors (and electricity prices) for different electricity prices (and demand).⁶

Energy Savings

Several studies over the past thirty years have evaluated the effectiveness of energy savings from home energy displays of varying sophistication. They exhibit a wide range of savings, with most finding savings between 5% and 15%.^{1,3,6,7}

Perhaps the most comprehensive study was of a pilot program carried out in Ontario, Canada. It evaluated the change in electricity consumption in more than 400 households during a year-long period where the homes had an energy display installed relative to an (up to) 18-month period prior to installation. After adjusting for weather and other confounding factors, the study concluded that the displays yielded about an 8% reduction in electricity consumption for homes with nonelectric space heating and 5% savings for homes without electric space and water heating.¹⁰ The relatively limited space cooling loads (and, hence, energy consumption) in Ontario may limit the universality of these findings to some extent.

Evaluations of pay-as-you-go programs in Canada and Ireland found savings of 15% to 20%, and 4% to 11%, respectively.⁶

Furthermore, the studies find large variations in energy savings among homes,¹ which appears to reflect residents' interest and ability to use the meters and the information provided.⁴ As Parker, et al., notes,¹ their small-scale field test of home energy displays "seems to indicate that interest and motivation were large factors in whether having the feedback device made a difference in energy use." The Ontario, Canada pilot found that about one third of participants did not intend to continue to use the device after the pilot ended.¹⁰ This implies that occupants with a strong interest in reducing energy expenditures or energy consumption will likely reap the largest savings from home energy displays.¹

Taken together, the studies also indicate that indirect information, i.e., periodic processing of raw energy consumption data by utilities to provide feedback at regular intervals, provide the most value for purchasing decisions, e.g., insulation, furnace, refrigerators, etc. On the other hand, direct displays more valuable for tactical operational decisions.³

The optimal combination of the type and frequency of information displayed to realize the greatest energy savings is not well understood.^{4,7} Furthermore, it is not clear that real-time feedback results in appreciably greater savings than less frequent (e.g., weekly or monthly) feedback,⁴ with a range of studies suggesting that real-time feedback realizes incremental savings on the order of 5%.³ Moreover, it is not clear, that more sophisticated displays save, on average, more energy than more basic displays. As Darby notes,³ a display that shows real-time energy consumption can provide somewhat similar feedback because it show how occupants' actions affect energy consumption. Limited testing (10 homes) of a sophisticated system in Japan that provided energy consumption data by end

use reduced site energy savings by an amount consistent with other studies (about 12%).¹³

Finally, the persistence of energy savings from home energy displays over several years is not well understood.^{1,7}

Trends

Currently, few households have residential energy displays. Several trends have the potential to greatly increase the deployment of displays in the not-too-distant future.

Relatively recent cost estimates for basic display systems range from \$100 to \$250,^{6,7} with an additional \$75 to \$200 for systems using clip-on devices.⁶ Sophisticated displays can cost appreciably more than conventional displays.³ Continuing decreases in the cost of electronics, communications (particularly wireless and PLC), and sensors, as well as the deployment of sensors that do not require an electrician for installation,¹⁰ promise to bring down the installed cost of systems while increasing ease of implementation.

Concurrently, utilities have a growing interest in reducing peak electric demand. At a basic level, this includes devices that alert residents of impending critical demand peaks and ask them to reduce their electricity consumption. Ideally, many utilities would like to use a combination of residential time-of-use pricing (TOU), real-time pricing (RTP), and automated demand response to manage peak demand.^{9,14} The latter two would require an advanced metering infrastructure (AMI) with meters capable of two-way communication with the utility to continually update prices⁶ to display time-varying electric rates and enact demand response measures (e.g., increase the temperature set point during cooling season).¹⁴ Such meters could readily communicate present the information shown by home energy displays to an in-home display.

As of a few years ago, many home energy displays could not readily support TOU, let alone RTP.⁶ More recently, displays with two-way communications that work with utility meters have come to market, presumably to support AMI initiatives. Plans for widespread deployment of meters that could support in-home energy displays are moving ahead in California and Ontario, Canada, and could greatly expand the use—or at least facilitate the deployment of—in-home energy displays.^{8,9}

Beyond increasing awareness of home energy consumption, widespread use of home energy displays might also increase understanding of energy consumption and its impacts. In this manner, widespread deployment of home energy displays could help enable additional energy savings.³

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