

## Residential Energy Monitoring

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**I**n two decades U.S. energy consumption will increase by roughly 40%, according to estimates from the U.S. Department of Energy's (DOE) Energy Information Administration. Currently, residential buildings account for about 21% of U.S. energy consumption and 37% of U.S. electricity consumption.<sup>1</sup> TVs and multimedia set-top boxes alone consume 6% of residential electric use.<sup>2</sup> Overall, homeowners do not have a way to identify offending systems and usage patterns that contribute to waste. Addressing these problems, or more appropriately, empowering individuals and institutions to solve them, is attracting increased technological development interest.

Attempts to address the issue by informing homeowners of simple remedies that have significant paybacks, such as more insulation, weather-stripping, and installing more efficient appliances have had some results, though many homeowners do not follow through on these recommendations due to upfront costs, perceived difficulty, or lack of time. The homeowners that do follow through usually have no more feedback on the improvement than a utility bill a month later, which usually obscures the benefit of the improvement they made through other energy use factors.

Other campaigns ask consumers to reduce use by turning down (up) their thermostats for home cooling (heating), similar to President Jimmy Carter's recommendation to wear a sweater. For some, this is not the most welcome suggestion. Other guidance provided by the popular media is helpful, but cannot address household-specific measures that would provide the most benefit for overall energy conservation.

### Residential Energy Monitoring System

Technologies to provide feedback on home energy use are being developed. One form of residential energy monitoring system (R-EMS) is a small display unit mounted on a wall. This display provides information on current and historic energy use from the home's major appliances and systems. The display also can present information on cost, carbon footprint, and other energy metrics. The information is sent to the display unit from sensors attached to the appliances/systems, or from a meter, such as whole-house meters for water, gas, or electricity. This information can be sent to Web browsers and cell phones.

Energy consumption can vary dramatically among households, even when 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 with the same appliances and equipment.

The homes exhibited a large spread in energy consumption, with the most energy-intensive home consuming 2.6 times more energy than the least.<sup>4,5</sup>

Occupant behavior has a major impact on building energy consumption. However, current utility bills usually only summarize energy costs and consumption for the prior month. This does not adequately help residents 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.<sup>5,6</sup>

Typically, just providing information to occupants will not appreciably reduce energy consumption because relatively few people act on the information. Specifically, people need a motivation to change, confidence that they can change, and feedback that the changes they make are having an impact.<sup>7,8</sup> Consequently, most successful approaches provide more frequent feedback and specific feedback on specific behaviors.<sup>5,7</sup> An effective R-EMS should provide both.

Several studies have shown that providing feedback to home occupants on their energy consumption can enable the occupants to reduce household electricity consumption by 5% to 15%.<sup>5,8,9</sup> Most commercially available R-EMSs provide information on overall household electricity consumption but do not categorize electricity consumption by specific end uses.<sup>5</sup> R-EMSs often do not show energy uses other than electricity, which is significant as up to half of a home's energy use can be from natural gas or oil.<sup>1</sup>

Several R-EMSs are being developed to provide end-use-specific energy consumption information to the consumer. Many of the new systems are designed for new construction, are somewhat costly, and require professional installation, but strides are being taken to remedy these challenges.

In the long term, a system deployed to enable centralized residential energy monitoring could be expanded to provide additional functions. Once basic information about residential energy consumption is collected, higher-level functions such as automated control and diagnostics could be incorporated that make use of this information. The system needs to be expandable to accommodate these functions.

In addition to providing energy management capabilities, the home network on which the R-EMS is built could also serve as a platform for providing additional, non-energy functions, such as health (on-person monitoring of health indicators) and security (unexpected occupancy or activity, excessive water use indicative of broken pipes, etc.)

Besides homeowner advantages, an advanced system could also benefit the utilities. The system could, for example, respond to a peak power demand signal, such as demand-based pricing, from the utility, with prior user permission, when using smart metering by postponing space conditioning while the occupancy sensors indicate the house is empty.

### Energy Savings Potential and Market Factors

At present, R-EMSs have negligible market penetration due to installation cost and complexity, as well as their somewhat complicated interfaces. With further improvements, this market penetration will likely increase. For example, data from Kastovich et al.,<sup>10</sup> suggest that an energy-efficiency measure with a three-year payback period will achieve a market share of just over 20% in new construction and around 70% in existing homes. These penetration levels suggest that, within a decade of commercial launch, a cost-effective R-EMS could be installed in at least 10% of the approximately 115 million U.S. households.<sup>11</sup> If they realize an average energy savings of 10%, after 10 years the R-EMSs would achieve annual energy and energy cost savings of approximately 0.2 quad and \$20 billion.<sup>11</sup>

Several factors suggest that these numbers could be conservative. Assuming that field studies demonstrate that the energy savings potential of R-EMSs is at least equal to that of whole-house electricity displays, i.e., between 5% and 15%,<sup>8,12</sup> utilities could offer rebates to install R-EMSs. In addition, the ENERGY STAR® program could promote R-EMSs by allowing effective R-EMS products to carry the ENERGY STAR label.

The technology trends to enable R-EMS deployment are favorable. Widespread deployment of smart meters<sup>13</sup> will make whole-house electricity measurement (the most costly measurement required for R-EMSs) readily available and provide a user interface that could be leveraged. The cost of the communications infrastructure is decreasing. Its incremental cost will be small as in-home wireless networks become more pervasive.

### Summary

Residential energy monitoring systems could allow homeowners to learn habits that will reduce their utility bills as well as their carbon footprints. Existing systems are beginning to reach the maturity required to allow cost reductions, simpler interfaces, and widespread applicability to existing residences and new construction. Further development and incorporation of automation capabilities and protocols will allow advanced features to further benefit users and utilities.

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