Thought Leadership
White Paper

Smart ambient monitoring supports a better context for care

Key Takeaways

As the world's population ages and incidence of chronic conditions increase, there's a shortage of healthcare workers and an essential need to create better healthcare outcomes. Digital strategies and tools—data science, machine learning models and smart space technologies—are creating a new frontier.

- Smart ambient monitoring looks for 'signals within the noise' by using energy and water usage data coupled with artificial intelligence and machine learning to provide insights on activities of daily living (ADLs)—namely movement, nourishment and hygiene—and notify caregivers when anomalies happen, enabling predictive notifications of potential problems.
- Smart ambient monitoring is proven to be as effective in identifying ADLs as other commonly used monitoring technologies.
- Used in conjunction with other commonly applied monitoring methods, this approach provides a more complete 'context for care' by enabling more detailed information about residents' daily activities at home, providing both reactive and predictive insights. So that caregivers better understand activities that are difficult to measure or accurately report on—like changes to nourishment and hygiene.

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Overview

Today's home healthcare monitoring technology tracks persons' activity levels, weight changes, blood pressure, sleep, bathroom habits, etc. via wearables, connected scales, monitors, as well as passive sensors. All of these devices provide data that can be used to help support longer, healthier, and more independent lives. However, many of these devices are perceived as invasive, require active use, or are wrought with error.

At Eaton, we are forging ahead in a new frontier built on our intelligent power management capabilities that can be put to work in new ways, specifically in recognizing and calling attention to early behavioral indicators of potential problems. This novel approach monitors home energy usage patterns via inferential sensing to separate the signal from the noise; using measurable inputs, like electricity and water usage, we can identify the hard-to-measure patterns of everyday life.

By scrutinizing energy patterns, smart ambient monitoring can uniquely provide passive, non-invasive, whole-home monitoring to enable predictive capabilities and proactive notifications of behavioral anomalies. Using intelligent hardware and inferential sensing, smart ambient monitoring stretches what's possible today—providing a more complete context for care.

Trends in play

A rapidly aging population, severe staffing shortages for nurses and home caregivers, and a large population with chronic health conditions are a reality. These trends are taking hold and are not expected to change course anytime soon.

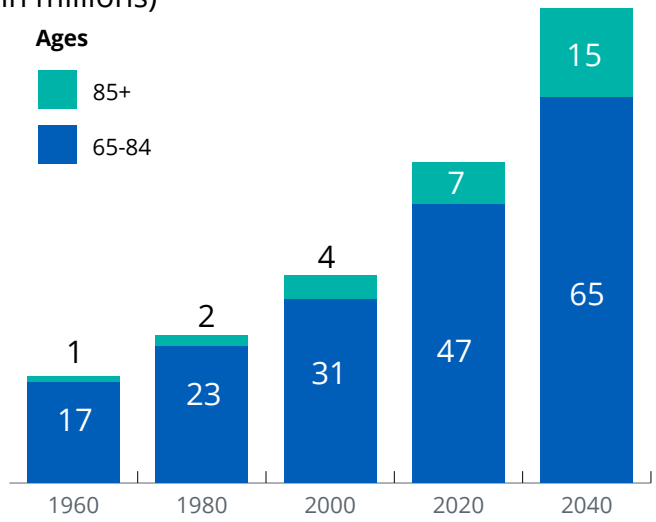
Globally, the population is aging faster than ever: one in six people will be 60 years old or older by 2030. In the U.S., the number of Americans ages 65 and older will be reach 80 million 2040, more than doubling (Figure 1).

At the same time, the global healthcare workforce will be short of around 10 million people by 2030. Already, 87% of U.S. nursing homes are dealing with significant staffing shortages and have a hard time hiring staff (Figure 2).

Healthcare is also shifting to the home, and homes are becoming smarter and far more connected. By 2025, up to $265 billion worth of care services are

Figure 1

Number of Older Americans, 1960-2040 (in millions)



Source: US Census Bureau (2004a, 2004b, 2004c)

expected to shift to the home, representing up to 25% of the total cost of care for Medicare fee-for-service and Medicare Advantage beneficiaries.

Globally, smart home devices are being put to use more, and expected to balloon over the next five years. The number of active U.S. smart homes is expected to reach 93.59 million users by 2027, with household penetration expected to hit 96.6% in 2027 (Figure 3).

Despite these market forces and increasing adoption of connected solutions, adoption of home monitoring technology has been an uphill battle. Many solutions are perceived as invasive, compromising residents' sense of independence at home. Further, today's technologies are also largely reactive, only able to respond after an event occurred.

For these reasons, applying smart ambient monitoring technologies to improve people's lives provides opportunity: implementing a solution that is both non-invasive for the resident(s) and predictive, using proven, readily available technology, and allowing care providers to get ahead of potential problems before they can occur.

Building a more robust context for care

How can remote caregivers know that an oven is left on for hours? Or that a resident is using the bathroom with greater frequency? While a motion sensor can help provide proof-of-life by detecting when someone enters a room, it is not designed to detect what is happening in a home. That is where smart ambient monitoring comes into play, providing insights on activities of daily living (ADLs), filling in details that can be missed with existing technologies.

Furthermore, by learning patterns, smart ambient monitoring can notify caregivers of atypical behaviors throughout a home. So, if the oven is on for an extended period of time or bathroom habits change, caregivers can get a notification of whatever is amiss and take action as required.

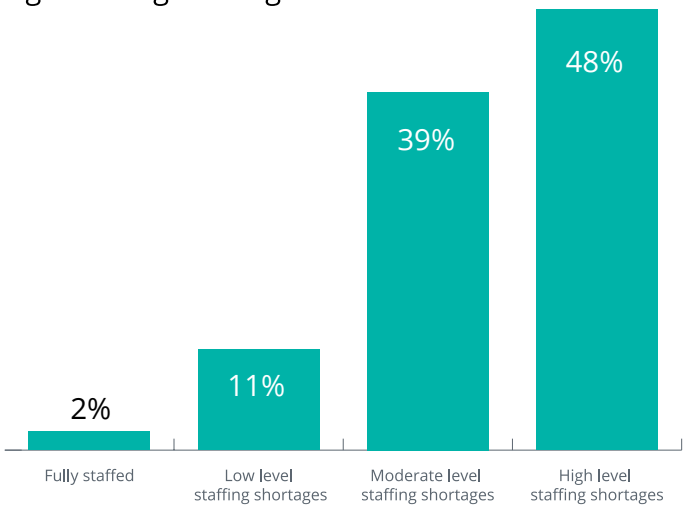
By learning home energy and water usage smart ambient monitoring provides insights and alerts to support at-home care. Whether residents are recovering from an acute illness, living with chronic condition or simply aging at home, insights on changes to nourishment habits (like skipping meals) or hygiene activities can support earlier intervention.

Creating a new frontier in home monitoring

Our approach to home monitoring leverages our inferential sensing capabilities to a household at the circuit breaker level and analyzes energy-usage patterns to discern the signals from the noise. Eaton's approach provides insights on residents' ADLs (e.g. movement, nourishment, hygiene) by learning their normal energy patterns. Leveraging machine learning, our smart ambient monitoring solution studies

Figure 2

87% of nursing homes facing moderate or high staffing shortages

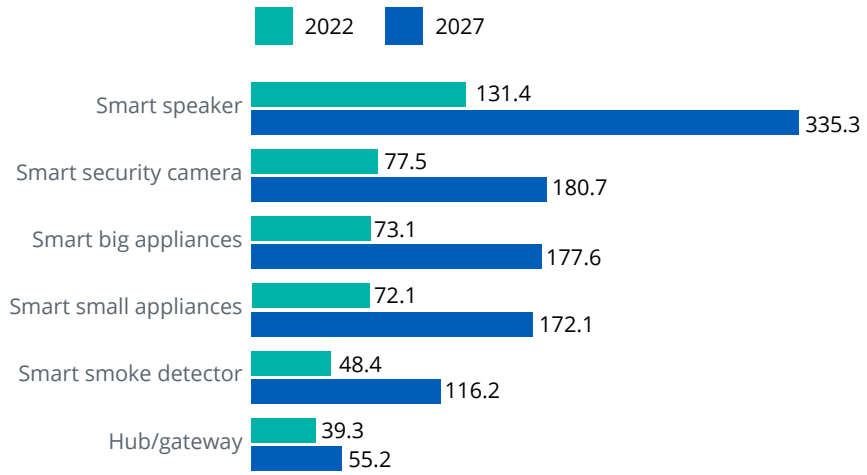


Source: American Health Care Association Survey Nursing Home Providers, May 16-20, 2022 n=759

activities of a given residence to understand "normal" or typical activities. Using our analytics services, we can identify changes in the normal patterns. Eaton can then provide notifications of changes from said normal behavior(s) for care providers to take timely action.

Figure 3

Estimated number of households worldwide with the following smart devices (in millions).



Source: Statista Technology Market Outlook, March 2022

Smart circuit breakers deliver foundational capabilities

Circuit breakers have been used for over a century nearly anywhere there's electricity to provide foundational safety function. Today, smart circuit breakers provide that vital functionality and so much more—now, connectivity and granular energy data from residences.

We reimagined what a circuit breaker can do to support intelligent power management: infusing cloud-connectivity and on-board metering (data collection) capabilities in foundational technology used in virtually any home or congregate care setting. We've combined our unparalleled experience in circuit protection with digitalization.

Comparing smart breakers to a traditional circuit breaker is like comparing a smart phone to a rotary-dial telephone. Smart breakers provide those essential safety functions (enabling homeowners to squeeze the most out of their energy systems, max out their onsite energy resources and stretch what's possible for smart home energy management) along with so much more: monitoring and (remotely) managing power use, providing granular data and control, plus protecting and safeguarding communications with secure data transmission from the source.

Smart breakers also are a game changer for home monitoring. They enable new intelligence from energy systems that can be used to passively monitor activities of daily living (e.g. ambulation, nourishment, hygiene), as well as help provide the data for early predictions and notification of behavior changes.

Importantly, Eaton smart breakers are designed for interoperability through an open communications platform. At Eaton, we have a long-standing commitment to interoperability. There is no manufacturer that controls all the energy infrastructure in a home, building or community. Everything needs to work together. When it comes to digital healthcare technologies, lack of interoperability and difficulty in integrating technologies is one of the biggest inhibitors to adoption. Eaton's analytics are designed to address this challenge to provide critical data.

* Inferential sensing refers to the process of making observations and predictions about an occurrence that cannot be directly observed by using available data. At Eaton, we are gathering energy usage data from activities of daily life to understand what a household's normal habits looks like. Based on energy data, we can observe when there is a deviation from normal, and we infer it may be an indication of a situation that a caregiver may want to address.

The Center for Intelligent Power applies machine learning to create new intelligence

Within Eaton's Center for Intelligent Power, our team of best-in-class data scientists are turning vast amounts of seemingly unrelated data into useful information, using artificial intelligence and machine learning (AI/ML) to identify patterns in energy usage and identifying when something is amiss.

Concretely, Eaton is collecting and learning the energy usage on each circuit and detecting pattern changes, such as appliances turning on and/or off. Our machine learning models learn the typical pattern of these energy-related activities over time, creating a unique energy fingerprint for a residence. Every residence has unique energy patterns. Moreover, every electrical appliance has a signature related to its use of electricity. These signatures, collected by our smart breakers over time, form patterns that become a given residence's energy fingerprint.

We developed algorithmic models that track and trend ADLs, as well as deviations from the normal behavior, to enable remote caregivers the ability to respond to changes in behavior. Eaton can detect when there's a significant change in activity levels and notify caregivers of changes, so they can take appropriate action.

In terms of ADLs, we look for significant changes in habits, such as missed meal or a significant decline in whole-home activity over time . For example, a typical morning routine may include turning on lights, opening the refrigerator, running the sink and coffee maker all before 10:00 A.M. These would be regular breakfast related activities. If they do not occur, then we would recognize that as an anomaly. When an anomaly is detected, a notification to the care provider or service, who would then make a phone call.

Research on applying energy data to activities of daily living

Leveraging the Intelligent Power Pilot, Eaton recently evaluated our approach compared to passive infrared sensors (PIR), which are electronic sensors measuring infrared light and are commonly used to detect movement in security and home monitoring applications. In this study, the Center for Intelligent Power's data science team compared the ADLs detected by PIR sensors to inferential sensing with data from smart breakers and water meters.

The Center for Intelligent Power grouped ADLs into three categories: movement, nourishment and hygiene. For this study, the focus was on the cooking (i.e. nourishment) and hygiene behaviors and patterns, analyzing 30 data points over the course of a day. We validated the data captured against the ground truth: information logged by homeowners for a total of 30 days.

The PIR sensors used were primarily motion sensors positioned in kitchen and bathrooms, whereas the inferential sensing provided whole-home energy and water data, using Eaton smart breakers and a water sensor on the household's main water line.

Eaton's data science team aggregated all the detected motion sensors data in predefined intervals for a single event or activity. Additionally, energy data (from Eaton smart breakers) tied to kitchen and bathrooms that occurred closely together was grouped as either a kitchen or bathroom visit. Finally, the Center for Intelligent Power overlaid the water data onto the energy data to infer hygiene related activities like toileting, bathing and cleaning (e.g. washing machine, dishwasher).

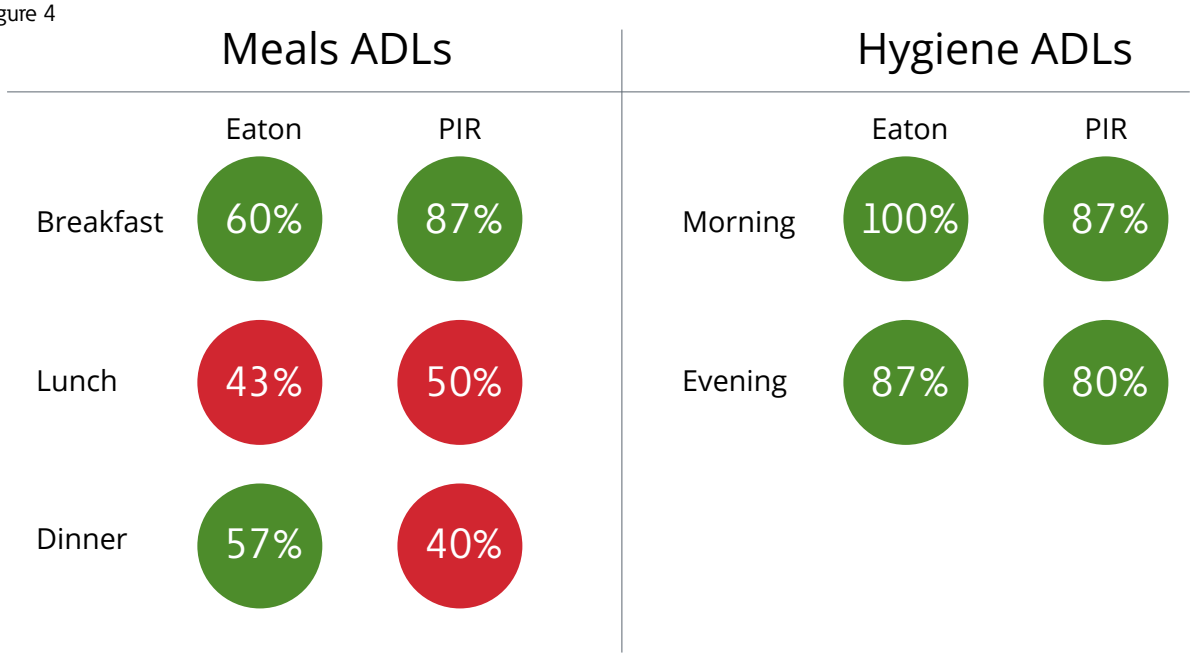
Eaton inferred that the residents were having breakfast at the first grouping of kitchen events of the day (i.e. nourishment ADLs). Similarly, we inferred lunch and dinner events from groups of energy activities at specific times. Additionally, for hygiene, Eaton focused on bathroom usage in the early morning, afternoon, and late evening.

We compared the PIR sensor data, the energy and water data, and the ground truth data. We found that combining energy and water information was just as accurate as PIR sensors. More interestingly, since PIR sensors essentially provide presence information, the energy and water data provided additional insights on the residents' behaviors related to nourishment and hygiene.

Validation Results (figure 4):

1. Within one hour of occurrence, measurement of ADLs related to breakfast meal activities are nearly as accurate as PIR (60% vs 87%)
2. Within one hour of occurrence, measurement of ADLs related to lunch meal activities are as accurate as PIR (43% vs 50%)
3. Within one hour of occurrence, measurement of ADLs related to breakfast meal activities are more accurate than PIR (57% vs 40%)
4. Within one hour of occurrence, measurement of ADLs related to morning bath activities are as accurate as PIR (100% vs 87%)
5. Within one hour of occurrence, measurement of ADLs related to evening bath activities are as accurate as PIR (87% vs 80%)

Figure 4



Note: While directionally promising, this study is still in process.

Conclusion

Early results from our research are promising, demonstrating that smart ambient monitoring—using inferential sensing and our smart breakers—is as accurate as PIR sensors. Further, smart ambient monitoring provides a more complete view of ADLs, well beyond the presence of residents in a room, calling caregivers' attention to changes in behavior patterns throughout a home. Based on a home's unique energy usage patterns, we can recognize early indications of potential problems and call attention to them. So, when eating or bathroom habits change, we can provide caregivers with proactive, simple notifications on anomalies.

We see smart ambient monitoring as complimentary to PIR sensing and other home monitoring technologies (e.g. WiFi). Used in conjunction with these other tools, smart ambient monitoring could provide even greater context for care, supplying caregivers with more information about ADLs through additional data that is both reactive and predictive. In other words, caregivers could better understand exactly how behaviors are changing and determine if those changes are related to residents' wellbeing.

Applying digital strategies and tools to home wellness indictors provides novel approaches to support safer, independent living. Smart ambient monitoring is already redefining the potential of intelligent power management with implications far outside of energy management. This is just the beginning—digital transformation will continue to enable new intelligence and insights.

About Eaton

Eaton is an intelligent power management company dedicated to improving the quality of life and protecting the environment for people everywhere. We are guided by our commitment to do business right, to operate sustainably and to help our customers manage power today and well into the future. By capitalizing on the global growth trends of electrification and digitalization, we're accelerating the planet's transition to renewable energy, helping to solve the world's most urgent power management challenges, and doing what's best for our stakeholders and all of society.

Founded in 1911, Eaton is marking its 100th anniversary of being listed on the New York Stock Exchange. We reported revenues of $20.8 billion in 2022 and serve customers in more than 170 countries. For more information, visit www.eaton.com.

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Printed in USA
Publication No. WP090001EN
May 2023

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