Measurement Changes Everything! A Disruptive Technology

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ABSTRACT

A cutting-edge technology that will make buildings and their inhabitants much more energy efficient is poised to enter the mass market. This technology is cost-effective and can be implemented on any scale from a single house to a national program. Remediation of our existing building stock represents the lowest-cost and most-immediate way to reduce both the national energy bill and the production of greenhouse gasses. While millions of dollars have been spent on efforts to improve the energy efficiency of homes and small commercial buildings in the U.S., these expenditures have been much less effective than they could have been because of our inability to collect relevant data and to learn from past experiences. This paper discusses what can only be described as a transformative technology that will vastly improve the effectiveness of these energy efficiency efforts and the programs that sponsor them.

The primary technologies discussed in this paper are circuit-level energy-use monitoring devices and the GreenNet Home Performance Database, which collects and makes accessible the information gathered through monitoring. The development of an inexpensive, user-friendly technology to monitor and store energy-use information on virtually all energy remediation projects and programs has the potential to revolutionize building standards, construction practices, and many of the trades and professions associated with the building industry. This paper discusses the potential impact of monitoring technologies on these industries.

The least-cost method to improve energy efficiency in buildings is to change the process, understanding, and decision-making of the inhabitants through better information. Accurate and detailed measurement of energy consumption, when presented in a manner that consumers and building managers can understand, can dramatically affect energy use. Circuit-level monitoring provides high-quality information to energy users in a manner that helps them make good energy-use decisions. Through the use of inexpensive on-site components combined with web-based user interfaces, many consumers can immediately reduce their energy usage and bills by up to 15% without investing in building energy upgrades.

Over the long term, the value of the data gathered through detailed energy metering of hundreds of thousands of homes and business will be almost incalculable. Detailed metering will provide concrete, performance-based feedback on the cost-effectiveness of every type of energy efficiency effort from large-scale utility programs to remediation work on single homes. Tracking actual energy use against project costs will provide performance-based evaluations and comparisons of both products and methods. Regulators will finally have the data to enable them to determine the most cost-effective incentive programs. Building performance contractors will finally have the data to help them determine the most cost-effective energy efficiency improvements on individual buildings. Considering the potential benefit of decreasing the cost and increasing the effectiveness of one hundred million energy retrofit projects, promotion and implementation of circuit-level monitoring should be a national priority.

This paper presents an energy-savings-through-measurement solution that is consistent with observations and recommendations from recently published studies. We will cite key points from these studies throughout this paper and describe how actual energy-use measurements will provide value as seen and recommended in the studies. Our objective is to describe how the employment of web-based sub-metering measurement devices, when combined with systematic collection of the data that these devices can provide, can be the most cost-effective strategy for reducing energy consumption in the U.S. over the next decade.

Unlocking Energy Efficiency

A central theme in this paper is "If you cannot measure it, you cannot improve it." This is a 19th-century quote from Sir William Thomson, aka Lord Kelvin. Wisdom from the late 19th century may serve us well. With this premise established, we are able to assert the corollary that "If you can measure it, you can improve it."

With the advent of "Smart" utility meters, it is now possible for some consumers to monitor their energy consumption giving them insight as to their energy-usage profile. But unfortunately, Smart Meters do not identify energy demand or performance at either the circuit or appliance level. A meaningful analysis of energy consumption requires power measurement granularity at the level of the specific energy device in order to begin to develop a thoughtful energy-efficiency strategy.

In the 2009 McKinsey & Company study "Unlocking Energy Efficiency in the U.S. Economy", the following point was made: "Despite numerous studies on energy efficiency, two issues remain unclear: the magnitude of the NPV-positive opportunity[1], and the practical steps necessary to unlock its full potential." The inference is that measurement of actual energy usage is fundamental to any solution. The more detailed the measurements, the greater the value in making energy-management decisions. This detailed information can be aggregated into a larger context to provide understanding of the system-wide impacts and trends that the measurements represent. A greater level of detail also allows for a more accurate projection of the NPV-positive opportunity of various energy management alternatives.

The central conclusion of the McKinsey study is, "Energy efficiency offers a vast, low-cost energy resource for the U.S. economy – but only if the nation can craft a comprehensive and innovative approach to unlock it. Significant and persistent barriers will need to be addressed at multiple levels to stimulate demand for energy efficiency and manage its delivery across more than 100 million buildings and literally billions of devices. If executed at scale, a holistic approach would yield gross energy savings worth more than $1.2 Trillion." This represents the ability to "reduce end-use energy consumption in 2020 by 9.1 quadrillion BTUs, roughly 23 percent of projected demand."

Access to continuous data on streaming energy consumption collected at the device level with added technical support will allow end users to properly assess energy consumption in a real-time environment. These data will also empower energy managers to set energy-optimization strategies for individual devices and the building as a system. Also pointed out in the McKinsey study is the following: ". . . measuring and verifying energy not consumed is by its nature difficult."

The McKinsey study also provides a useful grouping of four broad categories of proven, piloted, and emerging solutions. These categories are:

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[1] NPV stands for Net Present Value, a measure of the present value of future cash flows or savings, discounted in value back to Time Zero

- Information and Education
- Incentives and Financing
- Codes and Standards
- Third-party Involvement and Financing

In each of these categories, the actual and real-time energy-use measurements over time will help facilitate solutions.

Nowhere is reliable data more important than in determining the success of utility programs for energy efficiency. Utility programs are often plagued by poorly conceived and executed evaluation studies that draw inappropriate conclusions regarding the success of a program. Utilities, regulators, government agencies, manufacturers, and energy consumers are all struggling with developing "holistic" energy efficiency program implementation strategies. Clearly, measuring energy efficiency requires effective evaluation, measurement, and verification to provide assurance to stakeholders that programs and projects are achieving targeted savings. The accurate and consistent evaluation and verification of energy efficiency measures is essential to aligning the expectations of the various groups working on these programs.

Since the ability of an incentive program to capture energy savings typically determines the future funding of programs, the accurate assessment of effectiveness is essential. The lack of accurate and consistent assessment has played havoc with many incentive programs. An extreme example is utility-funded programs in California that provide services such as AC refrigerant charge (RCA) and HVAC duct testing and sealing (DTS). The current evaluation processes usually entail repeating the diagnostic tests or attaching data loggers months or years later and under a variety of changing environmental conditions. These methods attempt to do the impossible in order to recreate the exact conditions in which the original tests were performed in an attempt to determine the accuracy of that original test to ascertain the actual energy savings of the repair. The critical sources for error in both the original tests and the verification tests are instrumentation inaccuracy and technician expertise. Since there is no "standard" used in this process; comparing one unknown with another unknown is fruitless. In addition, data logging and pre and post equipment repair do not account for variations in operation. Real-time, and continuous energy-use measurement before and after the systems have been serviced would be a simple and indisputable way to determine the effectiveness of RCA and DTS energy efficiency programs.

Finally, the McKinsey report states, "Our research indicates that by 2020, the United States could reduce annual energy consumption by 23 percent from a business-as-usual (BAU) 3 projection...." Large-scale implementation of measurement of energy consumption at the device level is the most effective first step toward realizing this potential energy savings. The importance of continuous web-based, device-level power monitoring is now recognized in the HVAC industry as well as the wider community of professionals involved in energy efficiency.

The data from real-time monitoring is also useful to the building performance contractors, home and building energy managers, builders, utilities, and regulators. The next few sections of this report provide some examples of the many ways in which detailed metering will help establish new standards for these professions and conserve energy.

Behavior Modification through Measurement – The Least Expensive Alternative

Certainly one of the most inexpensive methods of reducing energy use is through the empowerment of commercial, industrial, and residential energy managers and home owners with real-time energy data so that they can make informed energy-management decisions. The study "Social Norms and Energy Conservation", published in June 2010, describes a variety of programs in which "Home Energy Report" letters are sent to residential utility customers comparing their energy use to their neighbors. The study reports that this information reduced energy consumption by 1.1% to 2.8% percent relative to baseline. One energy consultant currently working with homeowners suggests that energy savings of 15% to 20% are not unusual (on homes with monthly bills of at least $150) simply through lighting and appliance change-outs coupled with occupant education. The conclusion is simply that better-informed consumers make decisions that reduce their energy use and save them money. It is anticipated that systems that provide additional communication and management options such as sending alerts, suggesting corrective actions, and remote activation will stimulate even greater energy savings. Software features such as the ability to compare the occupant's energy use with others who live in similar houses in the neighborhood or community, or even in similar climate zones on the other side of the county, may well trigger competitive urges that will have more effect on reducing energy use than many expensive rebate programs.

With existing systems such as the Enalasys g-Meter™, users can be further empowered with easy-to-understand visual data accessed through a variety of personal-use devices such as smart-phones, tablets, and laptops. The key to getting people to use this technology will be creating simple and understandable user interfaces. With web-based systems, the interface designers can take advantage of protocols users have already grown familiar with through use of their computers and cell phones. Web-based systems also provide the advantage of enabling continuous improvement and adaptation to new and/or changing technology.

The Impact of Continuous Measurement on the HVAC Industry

In 2010, the California Public Utilities Commission (CPUC) and Investor Owned Utilities commissioned a study to identify the energy savings, impact of, and best processes to provide field diagnostic and repairs services to existing air conditioning, heat pump, and ventilation duct systems. The "HVAC Energy Efficiency Maintenance (HEEM)" study was issued in December 29, 2010. It addressed the issues and concerns regarding the maintenance of HVAC systems with a focus on providing clarity to the CPUC's "Big and Bold" goal of 50% improvement in the efficiency of residential and small commercial HVAC systems.

There are three reasons for citing this study in this paper: (1) the study identifies and elaborates on the uncertainties existing in the traditional field diagnostic environment where there is not sufficient use of technology; (2) it highlights the value of using sophisticated diagnostics for the evaluation, measurement, and verification; and (3) it recommends further development and deployment of smart meters and web-based metering. The HEEM study states, "...utilizing the emerging smart meter technology and other low-cost power monitoring devices is an exciting option for efficiently expanding data collection activities to thousands of customers." The HEEM study goes on to state, "Low cost (dedicated) power monitoring options are becoming more and more common. These tools should be explored in detail, and if proven reliable, utilized to the maximum extent possible in any future utility HVAC programs." The happy irony of the HEEM study is that the capability of some device-level monitoring systems available today not only meet but far exceed what was envisioned in the report. After decades of pouring millions of dollars of public money into energy efficiency projects, regulators finally have a way to find out the true effectiveness of the programs that they sponsor. No longer will discrepancies between various measurement and verification techniques cloud the picture of how effective a particular program is. Through the use of circuit-level measurement technology, incentive programs can be based on real savings. Measured energy savings will allow utilities and other sponsoring groups to apply "calculated" incentives to mass-market programs paying only for the energy savings actually captured, thereby showing measurable returns on their investments. No longer will utility programs suffer from inaccurate evaluation processes which put program funding at risk.

The following quote from the CPUC is evidence of the importance of accurate EM&V: "A technically sound EM&V process is the cornerstone of this Commission's compliance with Public Utilities Code Section 454.5(b)(9)(C)'s mandate that we ensure that the IOUs first procure all cost-effective energy efficiency resources and with the Assembly Bill (AB) 32 mandate that greenhouse gas (GHG) reductions be real, verifiable, and additional. It is of paramount importance to maintain the analytical rigor of our methodologies to count savings and financial benefits accruing from energy efficiency efforts. If these programs do not produce verified cost effective savings, we may no longer be able to justify spending ratepayer funds on energy efficiency or ensure that rates are just and reasonable."

Peak Load Offset

The implementation of Smart Meters by the utilities is a clear sign that "time-of-use" rate schedules will be applied to all residential utility customers in the not-so-distant future. This has the potential to dramatically change residential customers' utility bills and will provide a market demand for a way to control electrical consumption during peak hours and shift that consumption to off-peak times of use. The circuit-based metering is superbly positioned to meet that demand in a way that is empowering to the utility customer, easy to implement and use, and is affordable as well. This is a huge advantage over the other, less-granular monitoring equipment currently on the market.

One benefit of combining energy management and appliance-control functions in a monitoring system (the g-Meter™) is available now in areas where multi-tiered pricing for electricity has been implemented. Using their personalized web page, each consumer can pre-select what appliance they want automatically turned down or turned off when the monitor predicts that their energy use will put the customer in the next higher pricing tier. The benefits of this function will become even more obvious when utilities begin implementing time-of-use pricing. Through simple web-based controls, users can prioritize energy use. The system will even respond to unannounced rate changes because rates will be monitored by the web-based software. Systems that provide device-level monitoring with customer-controlled energy-use management functions will enable customers to save untold millions of dollars in high-tier charges and eliminate demand for power at the most critical times for the utilities.

Other Beneficial Uses of Monitoring Systems

Once a monitoring system is installed in a building, the potential uses for that system are limited only by the type of transducers installed in the building and the scope of the web-based software. While not all of these auxiliary uses save energy directly, some of them may represent added value in the eyes of the consumers. Any perceived added value would accelerate the acceptance of monitoring by the consumer and expedite the growth of the all-important database.

Energy-monitoring systems can provide services traditionally considered home automation. Services available with some of today's energy monitors (such as the g-Meter™) include control of appliances and equipment via the user's web page. This remote-control function can range from turning off and on light switches and receptacles to a true demand/response system that turns off the pool pumps when the price of electricity is about to be bumped to a higher tier. A user-friendly web interface can replace the notoriously complicated and often-ignored thermostatic controls on conventional HVAC systems. With web-based user interfaces, there is essentially no limit to the number of new uses that can and will be developed for both appliance-control and energy-management purposes. The eventual development of an open Application Programming Interface (API) will infuse this market with the same entrepreneurial energy and enthusiasm that currently drives the market for cell phone applications.

With the proper transducers and web-based software, an energy-monitoring system could also be used for environmental monitoring, especially monitoring of substances that are a threat to human health within buildings. The dangers from poor indoor air quality range from safety issues, such as a sudden increase in carbon monoxide due to a malfunctioning combustion appliance, to long-term health-threatening issues such as radon. It is suspected that monitoring of indoor air quality will appeal to many of the same customers as energy efficiency monitoring and will provide an added incentive for those people to invest in monitoring.

While alarm-type environmental sensors are available, they don't provide nearly as complete a picture of indoor pollutants as a tracking monitoring system can offer. With indoor-air-quality tracking, it is possible to do analysis of data and find patterns that will assist in analyzing the cause of the pollution and designing a solution. Certain pollutants may spike at night and could perhaps be reduced by installing a ventilation system programmed through the g-Meter™ to run on a nightly schedule.

The Potential for Continuous Measurement to Improve the Building Performance Industry

Since its inception, the building performance industry has been plagued by a lack of actual energy-use data. Consequently, it has been difficult to predict the effectiveness of energy remediation during the design phase and almost impossible to evaluate the benefit of remediation after it was completed. This is especially true for projects that include incremental improvements to a building. Detailed energy monitoring has not been an option primarily because of the high cost of monitoring systems that had the granularity to provide useful results. In an effort to compensate for the lack of real data, a myriad of computer models have been developed to try to model buildings in order to predict what effect various energy efficiency measures would have on the energy use of buildings. Despite the expenditure of hundreds of millions of dollars, energy software modeling remains famously inaccurate. To make matters worse, we have virtually no data documenting either the success or failure of the thousands of projects that have been completed.

An accurate and affordable energy-monitoring system will advance the building performance industry in four ways;

- It will enable practitioners to diagnose patterns of energy use in a building prior to remediation, which will help design effective projects.

- It will correlate energy use and occupant behavior after a project is completed to determine the success of the measures implemented.
- After the initial project, it will identify additional opportunities for remediation.
- It will enable the eventual compilation and analysis of hundreds of thousands of projects, which will enable statistical evaluations of which methods are effective and which are not.

Prior to affordable energy monitoring, determining historical energy use in a building was done through a disaggregation of monthly energy bills; however disaggregation of an energy bill is only useful for splitting the heating and cooling loads from the base load. It cannot break down the base load any further nor can it separate components of the heating and or cooling loads. Circuit-level monitoring can essentially provide as much detail on how the energy is being used as the building manager wants to gather. Using circuit-level monitoring to diagnose the energy use patterns of a home or building prior to the start of a project will enable the building-performance contractor to make much better suggestions for improving the energy efficiency of the building as well as to make more accurate predictions of energy use of a building after the improvements are made.

Perhaps the most appealing use of circuit-level monitoring for most building owners as well as most regulators is to provide accountability for the effectiveness of energy conservation measures. By monitoring the detailed energy use in a building before and after energy remediation projects are completed, the return on investment of those projects can be precisely determined. By monitoring indoor air temperatures and temperature stratification, even the occupant-behavior variable can be removed from the effectiveness evaluation.

While "building science" may be a science, its application is more of an art, which makes the transition to a home-performance-based business a tough sell to most conventional contractors. The hallmark of any science is predictability of an outcome based on a known set of inputs. The outcome of any building improvements is almost entirely based on the skill and experience of the contractor. Projections of anticipated energy savings are often exaggerated and rarely substantiated. This is especially true if the project includes something less than a total energy retrofit of the house. The energy efficiency improvements, from incremental improvements such as just air sealing or just replacing the duct system, are especially difficult to predict. Worse yet, many component (windows, HVAC, solar) salespersons will often claim energy savings that their products cannot possibly produce and that the homeowner cannot possibly verify after the fact – unless the owner has a circuit-level monitoring system installed.

The predictability of remediation projects will change dramatically once several hundred thousand circuit-level monitors have been installed and are feeding data to the Home Performance Database. Once the data are available from hundreds of thousands of projects, practitioners will be able to predict with a high degree of accuracy the potential energy savings from replacing windows versus adding another return air supply to the HVAC system. Once these data are available, our energy efficiency efforts will move from a hit-or-miss endeavor completely dependent on the skill of the practitioner to a real science where prescribed measures can be predicted to deliver projected results. The increase in efficiency of our energy efficiency programs made possible by accurate data will make efforts to save energy and reduce greenhouse gasses much more efficient and cost effective.

The Enalasys g-Meter™/GreenNet System

Installing hundreds of thousands of circuit-level monitoring systems in individual buildings will save considerable energy, but will not garner all of the benefits outlined in this paper, nor will it come close to realizing the potential of this technology to save energy. The Enalasys/GreenNet system is designed to maximize the potential of energy monitoring by combining monitoring technology with the development of a sophisticated, publically accessible database that will capture the data from hundreds of thousands of monitoring systems as well as home-performance and building-remediation projects. As these data build up, analysts from both the public and private sectors will be able to mine them for the information and trends that will guide future programs and efforts to improve the energy efficiency of buildings. Over time, data collected from those hundreds of thousands of projects will prove to be invaluable.

The twin pillars of the Enalasys/GreenNet system are the g-Meter™ and the GreenNet Home Performance Database. However, these are only the most recent ideas to germinate in the Enalasys energy lab. The California HVAC energy efficiency program, which requires the use of mobile diagnostic measurement tools to quantify the performance of HVAC equipment, was born in California in 2004. Those participating in this early program conducted equipment diagnostics and collected and reported data using three very different methods: (1) checklists and data, which were manually recorded, (2) call-in, which included calling a central number to record the diagnostics readings manually, and (3) automated reporting, in which diagnostic data were sent from the testing instruments directly to a computer database. The results of the automated-reporting method were free of human intervention and thus were more accurate, reliable, and useful for study purposes.

In 2004, Enalasys Corporation developed the automated refrigerant-charge measurement system called ChargeRite™. Today, the ChargeRite™ system is still the only digital technology to wirelessly collect and transmit comprehensive building and HVAC testing data. In 2006, California adopted the use of the ChargeRite™ system to provide immediate validation of HVAC work done in the field. Using the ChargeRite™, contractors were able to verify on site that their work met the utility program quality requirements. Because this process was automatic and reduced the chances of human error or "gaming," California changed its building department inspection requirements from a 1-in-7 job rate to a 1-in-30 job rate for work performed using the ChargeRite™ system. This significantly reduced the need for onsite visits by inspectors, which resulted in large cost savings to the state, consumers, and contractors.

The ChargeRite™ system initiated a progression of sophisticated EM&V tools and services developed by Enalasys. The g-Meter™ is a circuit-level energy-monitoring device that measures detailed energy use with a very high level of granularity. The g-Meter™ is installed near the main breaker panel, and small measurement sensors called current transducers (CTs) are snapped around each circuit line to be monitored. These circuits can be the various HVAC systems, electronics, appliances, pool pumps, or any device that consumes energy within the building vicinity. The g-Meter™ continually monitors the amount of energy being consumed and securely transmits that information to the greenNet.com Data Center every 5-10 seconds. The energy-use information is stored and displayed within greenNet.com and is available at anytime, anywhere, to anyone who has the appropriate permissions.

The g-Meter™

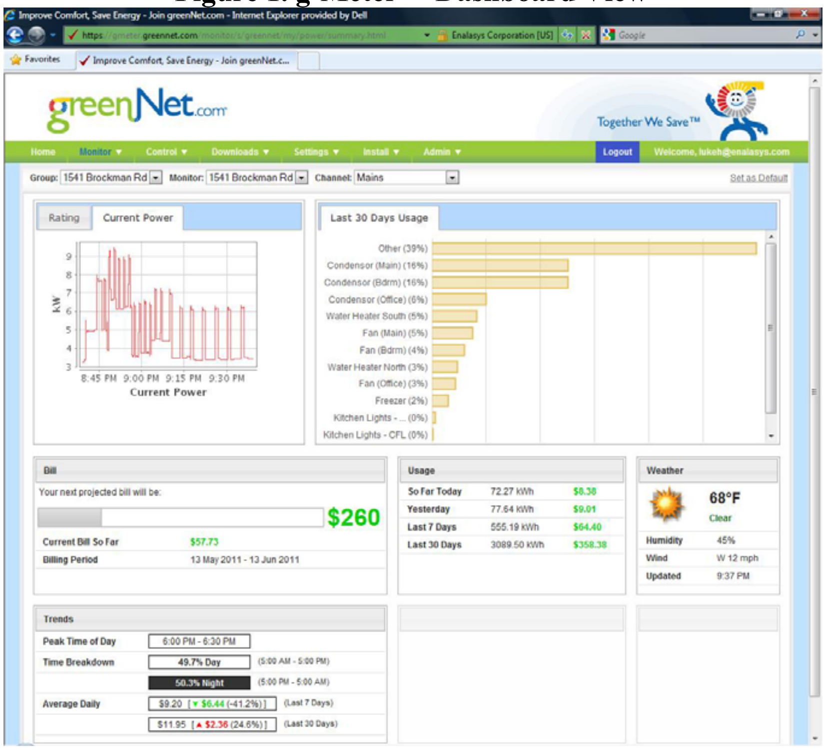
The g-Meter™, which is available for both commercial and residential installations, is highly accurate and is typically reported to be within 1% of the utility meter usage. In addition, the g-Meter™ operates using the same Zigbee technology as the Smart Meters currently being deployed around the country. This allows the g-Meter™ to work in conjunction with an existing Smart Meter. However, that is where the similarities stop.

The primary difference between the Smart Meters (also sometimes referred to as not-so-smart meters) and the g-Meter™ (nicknamed the Genius Meter) is that the Smart Meter is a utility company tool and the g-Meter™ is completely customer controlled and customer driven. With the g-Meter™, the customer determines what will be monitored, and the customer establishes parameters for energy use. The customer determines the priorities if he or she elects to control his or her energy use during periods of high rates. Given the suspicion generated by the utility-owned Smart Meters and the complaints about Big Brother intruding into customer's homes, the g-Meter™ may be seen by some as an antidote to the Smart Meter.

The Smart Meter measures only total energy usage broken down into 15-minute intervals. The g-Meter™ provides circuit-by-circuit energy readings (which can be broken down by appliance) every three to five seconds. The g-Meter™ identifies what areas are consuming the most energy and at what time of day. The various charts and graphs break down the usage by hour of the day and day of the month, as well as comparing month to month to see both the short- and long-term savings. There is also a live view available to see the second-by-second data of energy use. This enables the user to see the actual impact when individual appliances or devices are powered on or off.

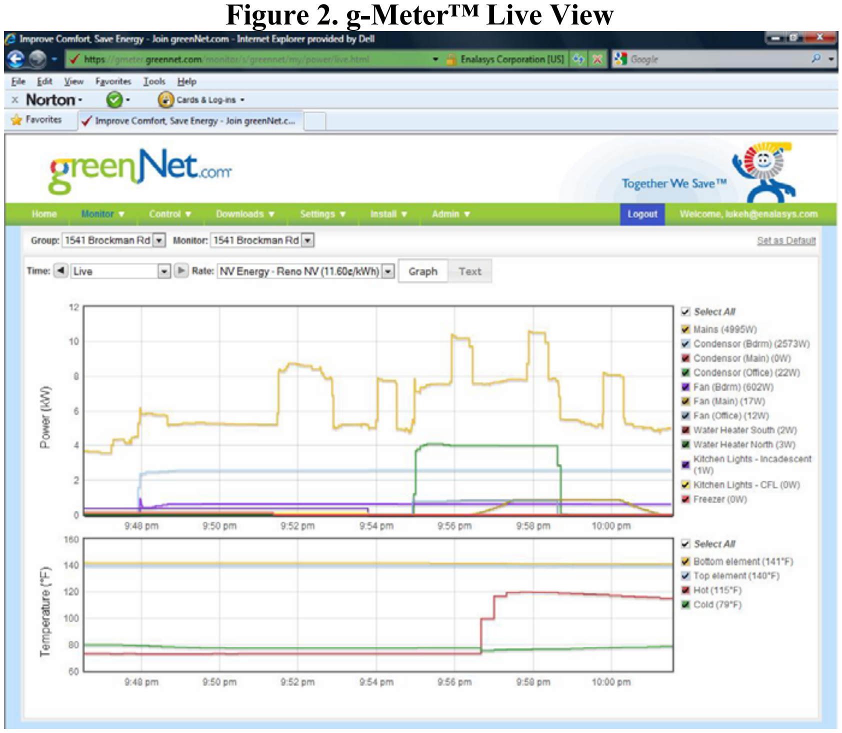
The g-Meter™ also provides proactive electronic text or email alerts if a certain area of the building or appliance is consuming more or less energy than a pre-determined threshold level. This threshold is configurable by the customer and can be turned on or off at anytime. The energy-use information is also emailed as a weekly scorecard to customers to keep them aware of their progress and help keep energy conservation top of mind.

Figure 1. g-Meter™ Dashboard View



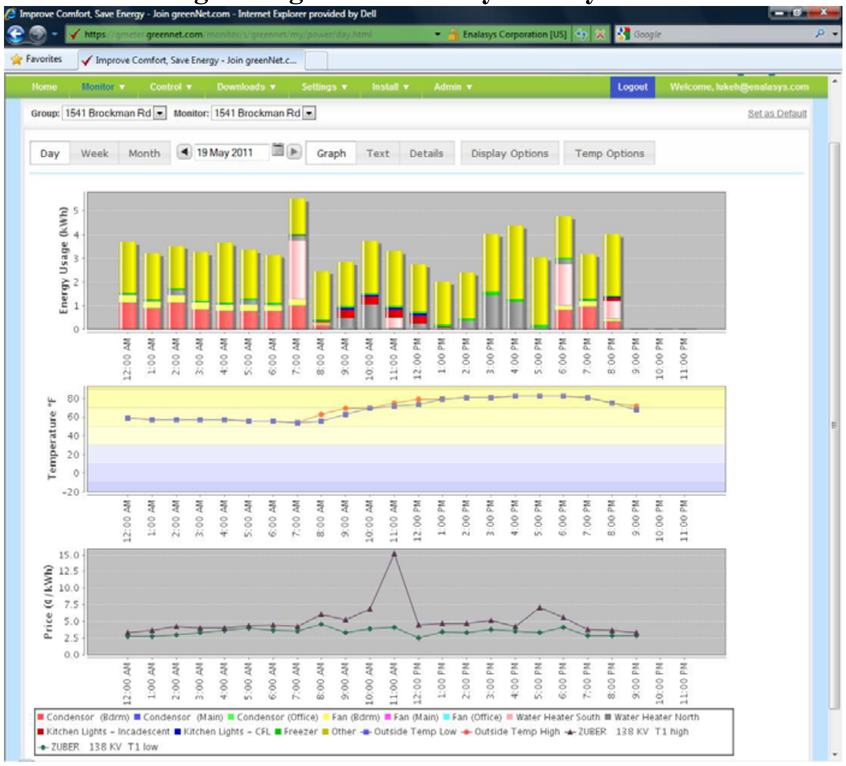
Source: greenNet.com website

Figure 2. g-Meter™ Live View



Source: greenNet.com website

Figure 3. g-Meter™ Daily History View



Source: greenNet.com website

The following quote from the Wall Street Journal ("The Power of Knowledge," February 28, 2011) by the owner of one of the installed g-Meter™ locations provides a useful example of recent user reactions. Says Jon Wellinghoff, chairman of the Federal Energy Regulatory Commission (FERC), these monitors "should be as widespread as TV sets." After purchasing a monitor for his house last fall Jon said "I estimate that I have cut my home power consumption—and my electricity bill—3% to 5% so far." A key observation is that "without the reporting from the g-Meter™, I may not have become engaged with my own personal energy consumption and may not have realized the potential impact of millions of consumers achieving the same modest energy savings."

The GreenNet Home Performance Database

The other pillar of the Enalasys/GreenNet system is the GreenNet Home Performance Database. Five years from now when a hundred thousand g-Meters™ have been installed, calculating accurate paybacks from home performance work will be simple and routine. Building packages of products and services into a credible and proven package of energy efficiency measures and doing financial projections for energy remediation projects will be easy. It will be easy because we will have collected sufficient data to accurately calculate both the energy savings and cost savings of the products that have been installed and the work that has been done in remediating hundreds of thousands of buildings. By providing a means to collect this data at an affordable cost, devices like the g-Meter™ will stimulate the paradigm shift that has to take place in order to deliver cost-effective building remediation to the mass market. The promise of a well-organized and thorough database that relates energy efficiency efforts and products with documented energy savings will be an inducement to regulators to support the wide and quick adoption of circuit-level monitoring.

Affordability

It must be appreciated that the primary determinant of the acceptance and proliferation of device-level monitoring systems, and the accumulation of data that they make possible, is cost. The idea of monitoring is not new, but monitoring has never before been offered at a price which would allow a home-performance contractor to install one as a matter of course on every job or even to install a meter as a loss leader in order to sell a job. g-Meter™ systems can be installed easily in commercial and industrial buildings for as little as a few thousand dollars and in homes for between $350 and $600. At these pricing levels, it is anticipated that a strong market will develop for the g-Meter™. Development of a mass market will enable further price reductions. Promotion and use of these products will result in continued development of these concepts with the eventual result being improved energy efficiency programs throughout the world.

Summary

Typical utility meters, temporary data loggers, or even Smart Meters do not provide the continuous detailed interactive energy monitoring at the device level necessary to properly assess energy consumption trends or events. Measuring energy at the equipment or appliance level provides users the granularity needed to enable them to make informed energy-management decisions.

The g-Meter™ and its associated web interface allows consumers to select which circuits or equipment to monitor. Energy measurements are displayed in user-friendly charts and graphs to facilitate easy review and analysis. In addition, the g-Meter™ is a viable solution to the real-time verification and quantification of energy efficiency measures. Using circuit-level monitoring, the energy measured prior to the installation of an improvement can be compared to the post-installation energy measurement to provide an immediate verification of installation as well as the basis for calculating energy savings. The g-Meter™ can aid utilities in gaining extremely high Realization Rates in many of their programs.

Conclusions

The potential for market transformation through the use of device-level monitoring and coordinated data collection has been acknowledged among energy efficiency experts for a decade or more. Successful implementation of this technology will inevitably lead to process improvements and cost reductions that may make building performance available to the mass market. The g-Meter™ technology is currently in use in over 250 buildings and is available now for commercial, industrial, and residential use. The sooner we build a large base of accurately monitored buildings, the sooner the data from those projects will be available for analysis and study. Given our national energy dilemma, use of this type of technology should be promoted and made available at every level.

Outside accelerators of g-Meter™ adoption include the following:

- Legislation encouraging or mandating measurement and verification by metering

- Having metering approved or made a requirement of incentive programs for energy efficiency
- The general distrust of utility Smart Meters
- Incentives to builders such as:
  - Cash rebates
  - Avoidance of energy-code mandates
  - Reduced costs for energy verification audits.

Case Study #1

The presentation of a case study provides anecdotal insight into the potential value of the g-Meter™ and its related devices in reducing energy usage and costs. The case is a good example of the incidents occurring with the use of the g-Meter™ and the value of its measurements. It presents a number of appliances' energy usage that can be measured and then adjusted or controlled that would otherwise be left undetected.

Retail Sandwich Shop

A g-Meter™ was installed along with other of its related measuring devices in a retail sandwich shop situated in a suite in a strip mall. There are five separate items identified creating savings for the shop owner.

- #1 – There is two air-conditioning units operating in the space. The reporting presented data showing that one of the units was running all night after closing. It was discovered that a circuit board was malfunctioning. The replacement of the circuit board cost $600.00 and the electric cost was reduced by $285.00 per month.
- #2 – It was determined the toaster oven was responsible for 1/3 of the energy usage. The toaster manufacturer specifications confirmed that the usage was within its expected range. The owner knows that the usage is within spec and that for the present nothing can be done.
- #3 – The ice machine has a door that occasionally gets jammed and stops producing ice. This is not good as ice is essential for the drinks. Attempts to prevent the door from jamming have not been successful. A related sensor is being installed that will send a text message to the manager that will provide an alert when this stoppage occurs.
- #4 – It was highlighted in the reporting that the oven used to bake bread creates enough heat to cause the air conditioners to come on. Baking starts at 6 am and the a/c will come on as early as 7 am. An economizer is being installed that will trigger the use of the fan only operation when outside temperatures allow. This reduces the use of the condenser and creates savings.
- #5 – Instead of a full lighting retrofit, a dimming mechanism is being installed that will allow reducing the lighting to as little as 20% for much of the day and adjusting upward as needed while the ambient lighting is taken into account. The result is reduced electrical costs for lighting.

The complete savings estimate for this case is not completed as it will require a few more months of operations, but the preliminary estimate is for an overall 40% reduction in energy costs. The costs incurred to realize the savings will be around $10,000 and the payback period is estimated at just over 2 years.

Case Study #2

A small commercial building in the area of Grass Valley, CA was metered after a gut remodel by very qualified building performance contractors. The contractors paid great attention to detail with far above average quality of products, workmanship and installation technique for the details affecting the building's energy performance.

A review of the after-occupancy energy-use data collected by the g-Meter™ revealed that the Heat Recovery Ventilation system (HRV) was running in an unscheduled manner.

Figure 1 shows the Heat Recovery Ventilation system running continuously for the 24 hours of February 15, 2011, a day on which the building was unoccupied. Conversely, Figure 2 shows the HRV in its OFF mode for the 24 hours of February 17, 2011, a day on which the building was occupied.

Figure 1

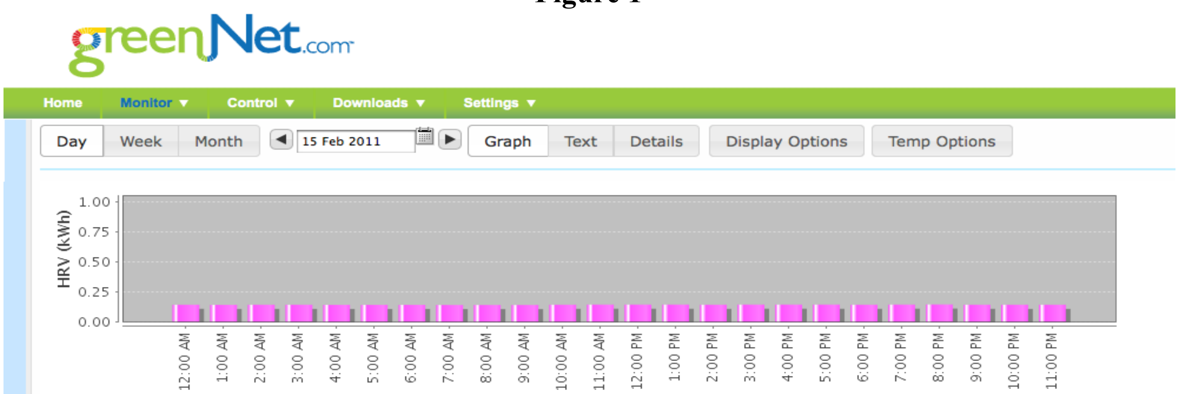
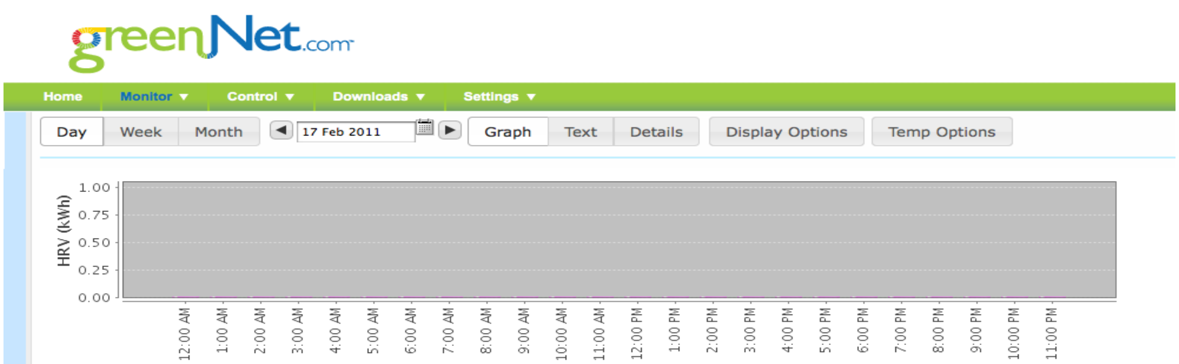


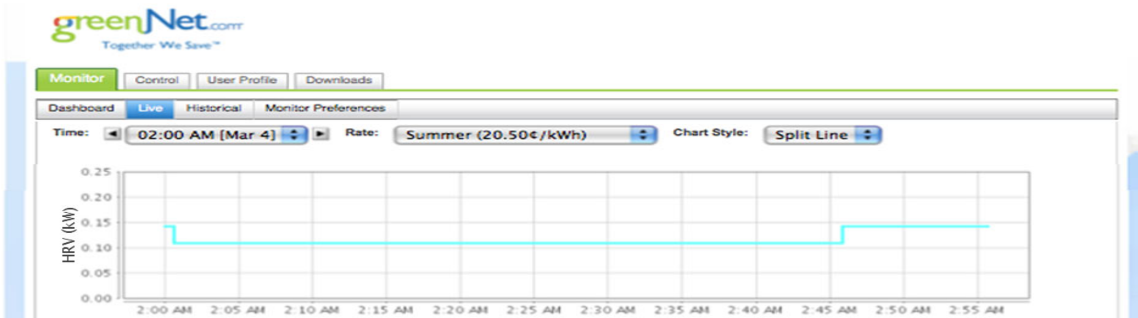
Figure 2



Review of the meter data showed the Heat Recovery Ventilation system running virtually continuously for month long periods of time. Analysis showed that scheduling the HRV to operate only during occupied hours would result in an 82% savings of the energy used to run the HRV during such a month long period.

Looking at more detailed g-Meter™ data (see Figure 3) revealed that the set back feature was not working properly. The unit was programmed to run for 15 minutes of each hour but did not actually cycle to its OFF state during the 45 minute set back period. Correcting this would result in an additional 12% savings (for a total of 94% savings) in HRV energy use as compared to a month long continuous run period.

Figure 3



These findings led to even greater energy savings to be attained. The energy used to run the HRV is small by comparison to the energy used to heat and cool the building. Because the building's heating and cooling systems are also monitored by the g-Meter™, potential savings could be calculated.

As an example, March 4, 2011 is considered. The high temperature was 55ºF and the low was 39ºF but hourly energy and temperature data for this installation were downloaded from the g-Meter™ website. Efficiency and fan flows were taken from the manufacturer's published data.

Calculations showed almost 15% of the heat produced by the heating system was lost through the Heat Recovery Ventilation system during the 24 hours, most of it during unoccupied hours. This demonstrated there was a significant opportunity for saving energy by controlling the HRV.

While the g-Meter™ can be used for this type of schedule control for the HRV, it was discovered that the HRV was only needed in cases of unusually high occupancy such as holding classes and seminars. Since this happens very infrequently, the HRV is now OFF almost all of the time and the savings opportunities discovered through the g-Meter™ are being realized by the building's tenants.

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