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EDITORIAL

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From the Editor

Shake, Rattle, and Roll

When I started as Editor-in-Chief for *Energy Engineering*, I let you know that I would try to shake things up from time to time (*From the Editor*, Vol. 113, No. 3). Apparently, I have been successful (maybe too successful when you read the last part of this message).

In *Energy Engineering* (Vol. 113, No. 4), I wrote "Decisions are made by those who show up." My goal was to stimulate readers to become more involved in the Association of Energy Engineers (AEE). The message definitely struck a chord in some readers who reached out to ask for more information about starting local chapters of AEE. David Hines from the Gainesville, Florida, area asked about starting an AEE chapter in Gainesville. AEE has several chapters around the United States, but surprisingly only one in Florida (and that one is not close to Gainesville). I say surprisingly because last year (September 30-October 2, 2015) AEE hosted the World Energy Engineering Congress in Orlando, Florida. Gainesville, home of the University of Florida Gators, is a large population center and should easily be able to support an active AEE chapter.

Meanwhile, Kanchana Marasinghe, CMVP (who plans to obtain his CEM), noted that attending AEE events is a bit difficult given his location in Edendale, New Zealand. Wanting to become more active in AEE, Mr. Marasignhe also asked about starting a local AEE chapter. While AEE has several chapters around the world, none is close to Edendale, which is on the southern end of the southern island (Southland) of New Zealand.

If you too are interested in starting a local AEE chapter, I recommend downloading and reviewing one of the AEE start-up kits for local chapters. Start-up kits are located at http://www.aeecenter.org/i4a/pages/index.cfm?pageid=3312. If you are interested in helping either Mr. Hines or Mr. Marasinghe, send me your contact information, and I'll pass it on. Starting a local AEE chapter is not complicated, but it does take effort and devotion. I have spoken with several AEE members responsible for starting local chapters, and they all attest to the effort but more so to the satisfaction once the chapter becomes self-sustaining.

As I write this message to you, it is mid-June 2016. The weather started cooling off last month (yea!) as we enter the local cool season. Better yet, the migrating humpback whales have reached the local waters. The next few months should have some awesome shows as the male whales breach (showing off) to capture the attention of the females. For those of you unaware, Myra and I began a new adventure in early 2015 moving to Ecuador. I generally write these messages while on my deck overlooking the Pacific Ocean.

Ecuador topped the news cycle on April 16, 2016, when the country was rocked by a massive (magnitude 7.8) earthquake. Several cities and towns in northwestern Ecuador were decimated. Since then, the area has been rocked by scores more quakes (aftershocks) ranging from magnitude 4.0 to 6.9. Talk about shake, rattle, and roll! Things have quieted down lately; it has been 10 days without a measurable aftershock. I remember the ground rolling under my feet when the quake hit. We were (and continue to be) lucky.

When we moved to Ecuador, we initially lived in a city much closer to the quake's epicenter. In fact, the first two buildings we lived in (as we searched for a more permanent home) are now condemned as a result of earthquake damage. (I must admit that I was impressed by the outpouring of support from the Ecuadorian government, the local Ecuadorian communities, the local expat communities, and the worldwide community which came to lend a hand to those affected and continue to assist in the reconstruction effort.) Our current home was undamaged by the quakes. As I said, we are lucky.

When I said that I wanted to shake things up, I meant it more figuratively, not literally. Still, a little excitement stimulates the soul. I wish all of you well and hope you are as lucky as I am. I think it is time for me to walk to the beach and watch for whales.

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Measurement and Verification of Industrial Equipment: Sampling Interval and Data Logger Considerations

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ABSTRACT

Measurement and verification (M&V) of energy efficiency projects is an important activity for energy managers, government agencies, building owners, and utility representatives. Misapplication or misunderstanding of M&V protocol requirements can cause significant error in energy savings calculations. Additionally, incomplete knowledge of how common data loggers function can create confusion around the measurements being taken and the results being reported. This article seeks to further the understanding of data collection intervals, M&V costs, and M&V plan uncertainty. Additionally, a detailed description of how several types of electrical data loggers function is presented, showing the advantages and potential disadvantages of each.

INTRODUCTION

Measurement and verification (M&V) of energy savings has been an important topic among energy managers, governmental agencies, building owners, and utility representatives since the first energy crisis in the mid-1970s. And, as utility incentive or rebate programs become more ubiquitous across the U.S., more industrial companies are pursuing viable energy efficiency as a way to reduce bottom line costs. The utility incentives can reduce the simple payback of these measures to be competitive with other capital projects within the company, such as new product development and process efficiency improvements. The utility programs require M&V to qualify the projects for the rebates and incentives. Furthermore, these industrial energy efficiency projects include variables which can be more complex than commercial building projects, such as varying production output, work schedules, shift efficiencies, and others. These are added to the common commercial sector variables such as weather and occupancy loads.

Given the abundance of information, it is worthy to note that there is still significant confusion among energy managers regarding data collection methods, development of M&V plans, and errors associated with application of M&V protocols, whether proper or not. This may be due to the fact that M&V is not a common part of day-to-day operations for most energy managers, but rather done possibly once or twice a year to justify a project or procure a rebate. The authors have observed that the infrequency of data logging and M&V techniques lead to improper applications or use of out-of-date information and/or methods. Also, because power and energy measurements typically require some knowledge of electrical and mechanical safety procedures, it is quite common for an energy manager or energy engineers to develop the M&V plan, which in turn is implemented by a technician, such as an electrician. Without good communications between the engineer and technician, the data may not represent the intent of the project. This can either be caused by mistakes by the technician in carrying out a properly designed M&V plan, but more commonly can be a result of the technician following a poorly designed M&V plan, developed by an engineer with insufficient knowledge of data gathering techniques.

This article seeks to explain how data logging intervals are commonly misapplied, and what the perceived and actual requirements are within the governing M&V framework. The discussion and guidance provided should lead readers to an understanding that will lead to better M&V plan design and implementation. Further, the article will provide relevant information on several types of available electrical data loggers, their capabilities, their costs, and the implications of using each for pre- and post-retrofit M&V of energy efficiency projects.

BACKGROUND

A brief history of M&V is given in the Energy Management Handbook, chapter 27 [1]. In the 1980s, M&V of energy savings became important when utility incentive, rebate, and loan programs were prevalent. In addition, several US Department of Energy (DOE) programs targeted residential and commercial buildings. These programs required proof that the implemented energy efficiency measures had performed as expected and achieved the savings that were promised. Successful and not-so-successful energy efficiency projects have been well documented by Waltz [2], Roosa [3], McBride [4], and others. Note that savings cannot be directly measured, because savings is the reduction of usage, so over time performance contractors and energy engineers developed methods that provide a high level of confidence in projections or estimates of savings, often based on measurable quantities.

The North American Energy Measurement and Verification Protocol (NEMVP) was first published in 1996, and later expanded and re-named the International Performance Measurement and Verification Protocol (IPMVP) [5]. This set of measurement protocols gives guidance on the type of M&V required to quantify and report energy or cost savings.

More recently, the International Standards Organization (ISO) released ISO 50001:2011, which is the overarching standard for an energy management system [6]. ISO 50015:2014 "Measurement and Verification of Organizational Energy Performance — General Principles and Guidelines" [7] is a companion standard that addresses M&V. This standard is similar to IPMVP in that it provides an overview or framework of how M&V should be conducted and what M&V plans should include. ISO 50015 includes guidance on M&V plan construction, data gathering, uncertainty, and reporting.

While many examples are given for different types of energy efficiency measures, facilities, and savings goals, no specific M&V plans are defined within the current IPMVP framework or ISO 50015. In fact, the IPMVP preface specifically states that "Each user must establish its own specific M&V plan that addresses the unique characteristics of the project." [5]

Specific guidance on M&V plans was offered by the DOE when they published a guide titled "The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures" [8] in April 2013. This guide offers specific guidelines that should be followed for many specific energy efficiency measures, including commercial lighting, residential boilers, and several other measures that are commonly implemented as energy efficiency improvements. The information published in the Uniform Methods Project includes directions for types, levels, and durations of measurement, equipment types, data handling, and metering methods. However, only 7 specific measures are covered in detail, and these measures are largely related to the residential and commercial sectors only. There are no industry-specific measures covered.

Chapter 9 of that document discusses "Metering cross-cutting protocols" at a high level, but does not include specifics for these types of measures. Related, ASHRAE Guideline 14 [9] addresses the technical aspects of commercial building M&V in great detail.

IPMVP OPTIONS

IPMVP provides four options for M&V. Option A is "partially measured retrofit isolation," where many parameters can be stipulated. Option B is "retrofit isolation," where all parameters are measured. Option C is "whole facility," where data from the utility revenue meters are used to determine savings from all measures combined. Option D is "calibrated simulation," where, for example, a building energy modeling program such as eQuest [10] is used to determine the savings from one or more measures.

Good savings estimates of simple measures with constant energy usage (e.g. lighting retrofits) can be determined with single power measurements, taken pre- and post-retrofit, and known annual operating hours. Little guidance is needed on determining savings with these measures, which use IPMVP option A; and in fact, some utility programs allow prescriptive rebates, with operating hours, fixture wattage, and other parameters all being stipulated. In these cases, nameplate information and a count of the pre- and post-retrofit units is all that is required.

Multiple measures with system, weather, and production interactions may require multi-variable regression analysis, and metering individual measures may not provide sufficient information. Kissock [11] describes methods to perform this complex analysis with relatively simple inputs. The Department of Energy EnPI tool [12] is another example of such regression-based analysis. These models typically conform to use with IPMVP option C, using data from the utility revenue meters.

IPMVP option D is intended for use in commercial building simulation modeling, and doesn't have broad application in industrial energy efficiency. Industrial simulation can be done, and is used for some selected industries where the simulation provides significant benefits to production efficiency, output, and other measures. The complexity of doing industrial process simulation for individual facilities makes the endeavor too costly to be justified for energy efficiency programs, so IPMVP option D is rarely used for industrial facilities.

Other measures require data logging at specific intervals over set periods of time. These measures may be small in comparison to the overall energy usage of the facility, have no influence from weather patterns, or be measures where it is relatively easy to access and measure individual energy usage. These measures will use IPMVP option A or B. As mentioned above, M&V plans that use option A may have some parameters logged and others stipulated, either through the use of spot measurements, facility inputs, engineering experience, or a combination of these. Option B requires that all parameters be measured, so data logging is more prolific in option B M&V.

For all M&V plans that use option A or B, proper application of M&V methods can increase the efficacy of measures by reducing the overall M&V costs associated with the measures. However, the improper application of M&V methods can inaccurately estimate savings, thereby either inflating the claimed savings and providing an improper assessment of the project cost effectiveness, or underestimating the savings, which reduces the apparent cost effectiveness of the project.

THE M&V PLAN

The guiding principles of M&V that are set forth in IPMVP are intended to provide reasonable accuracy in the determination of actual energy savings given the many variables that could take place in any energy efficiency project. These principles include "M&V costs should normally be small relative to the monetary value of the savings being evaluated," and "Accuracy tradeoffs should be accompanied by increased conservativeness in any estimates and judgments" [5]. To these ends, the M&V plan should consider the cost of any required M&V activities and determine the level of M&V that reduces uncertainty in the savings estimates without unnecessarily reducing the efficacy of the energy savings project.

The Cost of M&V

Cost savings is not the only goal of energy efficiency projects, but it is usually the most important driver of the projects in the commercial and industrial sectors, so expensive M&V plans can act to reduce the implementation rates of these projects. Quantitative uncertainty analysis can be used to determine the proper levels of M&V that are acceptable for each project, and Mathew [13] has shown that this can be simple to integrate into the planning stages of any energy efficiency project.

Oftentimes, an M&V method is selected and the M&V plan is developed based solely on the measure being implemented, without regard to the cost of M&V compared to the savings of the project. Consider compressed air efficiency projects for example; it is common to see option B selected, with 2 weeks of data logging required regardless of scale or scope. However, the DOE Compressed Air Sourcebook states, "Energy savings from system improvements can range from 20 to 50 percent or more of electricity consumption" [14]. Clearly the electricity consumption of the system is related to the size of the system and the operating hours of the system, so savings available for a compressed air project is related to those variables.

As an example, consider a fully loaded, continuously operating compressed air system with a single 50-hp air compressor. This system may have the opportunity to reduce operating costs by 50%, with an annual savings of around $15,000 (based on $0.065/kWh and $10/kW-mo). A different compressed air system may have the same opportunity to reduce operating cost by 50%, but if the second system is much larger, with a single 500-hp compressor, the savings could be 10 times as much. In these two systems, the same M&V plan might have exactly the same cost, but its impact on the overall project cost might be 10 times greater.

For the smaller system, this could mean that an expensive M&V plan reduces the efficacy of the project to a level that makes the project untenable to the decision makers. For the larger system, the less expensive M&V plan might provide a very high uncertainty level, in terms of dollars. This high cost uncertainty may equal or outweigh the potential savings of the project, making the M&V plan inadequate for the project. Therefore, measurement uncertainty for any M&V plan should also be determined and both should be considered during the proper selection of the M&V plan for each individual project.

METHODS FOR ESTIMATING ENERGY SAVINGS

There are five methods available for determining the parameters needed to estimate energy savings. These are stipulation, spot checking, current logging, energy logging, and power logging. These methods have increasing accuracy and increasing costs, from stipulation with low accuracy and low cost, to power logging with high accuracy and potentially high costs. Because logging energy and logging power require very similar equipment and have similar accuracies over long periods of time, these are considered equivalent for the purpose of determining uncertainty and cost.

Because savings can't be measured, even the most rigorous M&V plan has some uncertainty. Take the case of an M&V plan where all parameters are logged for a full year before and a full year after the implementation of an energy efficiency project. Even when the data is normalized for production, weather, and all other variables that affect energy intensity, the difference between the two measured periods is still an estimate of savings with some error. That error may come from calibration of devices, unplanned outages, equipment maintenance, other production related effects, or any number of other sources. This is the baseline uncertainty.

Less rigorous M&V plans add uncertainty to this baseline, which is referred to as "additional uncertainty" within this article. Lee [15] showed that stipulating operating hours can add 30% additional uncertainty. The American National Standards Institute (ANSI) standard for voltage gives an acceptable tolerance for utilization voltages of -13% to +6% [16]. Dooley and Heffington [17] showed that actual service factors of electric motors can range from 6% to 109% of rated horsepower, so spot checking of varying loads, or stipulating electric motor loads based on nameplate ratings can add uncertainty of up to 94%. Baldor electric motor specifications show that the power factor of premium efficient electric motors can vary from 11% to 17% across their normal operating range, so stipulating a power factor or spot checking the power factor on a varying load can add this much uncertainty. Based on these added uncertainties, the cost uncertainty associated with a single measure energy efficiency project can be estimated.

Proper Sampling Intervals

As the M&V plan is being developed per the IPMVP framework, special attention should be given to the measures that will be logged per option B and how the logging will be implemented. This is an area where little expertise and significant opportunity for mistakes may exist. The most common mistakes occur with choices of data logging and sampling intervals.

As an example, logging motor energy usage at 1-minute intervals is often required by utility incentive programs when measures use IPMVP option B. This is usually because of a misinterpretation of the actual IPMVP requirements. Section 4.7.3 states; "The method of measuring electric demand on a sub-meter should replicate the method the power company uses for the relevant billing meter" [5]. Further, it specifically states that if the utility uses a fixed 15-minute demand window "the recording meter should be set to record data for the same 15-minute intervals" [5]. This section goes on to discuss sliding demand windows and makes the general statement that if a sliding window is used, the demand window can be estimated "…by recording data on 1-minute fixed intervals…" [5] and then recreating the sliding window during the data analysis phase. Data logging intervals of 1-minute are mentioned in two other places in the text, once to describe a spot check of a simple measure, and once in the same context as above. The protocol never specifically states that data must be collected at 1-minute intervals for any practical purpose of determining actual motor energy usage.

In fact, intervals of 1 minute may or may not actually capture the true operating characteristics of some motor operated systems. For instance, an air compressor with load/unload controls may cycle in less than 1 minute, and the data collected at 1-minute intervals may only record the fully loaded or fully unloaded power for significant periods of time. Rather than specifying a data collection rate, data should be collected at the proper intervals to define the dynamic performance of the system.

Alternately, when fine sampling data is not required, a data logger with the ability to oversample (meaning that data is sampled more times than are recorded) and record averages can be selected. These types of loggers may sample data at very high frequencies, but only record the average of those samples to memory at a specified interval. In the case of the load/unload compressor, some data loggers may be able to oversample at 1 second intervals, and then record the average of those readings at 15-minute intervals, giving true average power or true energy consumption. In this case, a graph of the recorded data will not be truly representative of power over time, but will represent average power over time. This is the same methodology that utility meters use, and will produce the same results as using a utility meter.

Several types of data loggers are available on the market today, with different capabilities, accuracies, and considerations regarding ease-of-use. So, proper application of each type or style of data logger relies on a solid understanding of how they work and how they can be applied to measuring power and energy usage. The next section presents a discussion of three types of data logger systems: current loggers, energy loggers, and power loggers.

EQUIPMENT CONSIDERATIONS

The specific devices that are used to measure and monitor energy, power, and other necessary data for M&V plans should be installed by knowledgeable technicians per the manufacturer's instructions for each device. Installation instructions are typically quite thorough and complete, and equipment manufacturers typically provide support to end users of their equipment as needed.

A review of the literature shows that applications and uses of data acquisition systems have been well documented since the 1970s [18-20]. Data acquisition systems are often permanently installed in an industrial facility, and these are meant to provide real-time data to plant operations personnel. These systems can typically provide data logs that can be analyzed off-line for different purposes and these data should be used whenever possible for M&V activities because the data is available and adds no cost to the project budget.

Today, portable data loggers are widely used for M&V. These devices can be inexpensive, easy to install and operate, and provide the necessary precision and accuracy for M&V activities. These devices record and store data, which can later be extracted and analyzed. Modern data loggers have significant storage capacity, high sample rates, small size, and high durability. The large number of manufacturers means that data loggers are readily available for most project needs. State equipment loan libraries, utility plan implementers, and utilities themselves may be able to provide data logging equipment for an M&V project without directly adding cost to the project. The choices are many, so it is up to the M&V professional to ensure that the proper data loggers are selected for the project, and that these are utilized correctly.

CURRENT LOGGING

Logging electrical measurements is relatively straightforward, and can be accomplished with non-destructive means at a low cost. Current can be logged with a current transducer (CT) and a data logger. The current transformer has been used to successfully measure electrical current since it was patented by Edward Weston in 1888 [21]. The portable data logger is a more modern construct, having been introduced in the 1980s to replace chart recorders with solid-state devices that could capture voltage and current signals and store them digitally.

Typical current transducers are solid core current transformers, split core current transformers, and Rogowski coils. Solid core CTs are commonly used in permanent installations, because they require the conductor to be passed through the center of the device, requiring the circuit to be open while doing so. Split core CTs are the most common transducer used to temporarily measure and log current. These have reasonable accuracies, but their large size and rigid space limitations are a disadvantage. Additionally, CTs have a strict current limitation, and the output signal saturates at that limit, meaning that any current above the limit cannot be determined.

Rogowski coils are another type of current transducer that have arisen in recent years as the transducer of choice for M&V professionals. The Rogowski coil is a flexible transducer that produces a scaled time derivative of the primary signal [22]. This signal requires the data logger or transducer set to have some computational capabilities in to reproduce the primary current signal in an understandable form. Modern data loggers have all the computing power necessary to perform this function.

The flexible transducer is a major advantage over rigid CTs and is likely the primary reason that technicians prefer to install Rogowski coils. The other major advantage that should be considered is that error in Rogowski coils is a function of the primary current being measured [23], where error in CTs is a function of full-scale rated current. This means that CTs must be selected based on the magnitude of the current being measured; a maximum current to ensure that the CT does not saturate, and a minimum current to ensure that CT error is acceptable. Because Rogowski coils do not saturate, the maximum current is limited only by the diameter of the conductor being measured, and the minimum current is not a limiting factor because the error scales with current.

One disadvantage that should be considered is the Rogowski coil's need for power to produce a signal that the logger can record. When the Rogowski coil is used as a stand-alone current transducer, it will likely require either a battery or 110-VAC source. In an industrial setting, this may require an extension cord to be routed from a wall receptacle to the electrical panel with the transducer, and this may very well be unacceptable to the facility operators, not to mention inconvenient to install.

While current logs are valuable to engineers and maintenance personnel, the goal of most electrical M&V plans is to measure energy usage in kWh. Three phase current is related to energy by the formula:

kWh = V*A*PF*sqrt(3)*OH/1000

When current is logged, the other independent variables voltage (V), power factor (PF) and operating hours (OH) can present significant uncertainty.

The uncertainty related to actual operating hours is difficult to manage, because plant employee working hours and equipment operating hours can differ significantly. Lee [15] showed that incorrect assumptions regarding operating hours can affect savings calculations by up to 30%. Luckily, the data logs will provide a very precise representation of the equipment operating hours during the M&V period, and these can be compared to any stated operating hours. Projecting the recorded operating hours over the course of a year is a simple arithmetic problem, producing an estimate of annual operating hours. Holidays and plant shut downs must be considered because any interruptions in normal activity during the logged period will reduce the logged operating hours and could produce an unreasonably low estimate of annual operating hours. Conversely, if the equipment normally shuts down for some period outside of the logged period, not taking these shut down hours into account could produce an unreasonably high estimate of annual operating hours. Any assumptions regarding operating hours should be clearly stated and justified in the M&V report.

Voltage, particularly in an industrial facility, can vary during the course of a normal day as plant equipment loads change, HVAC loads change with temperature, or utility grid loads change for various reasons. The Western Systems Coordinating Council (WSCC), a group of 86 western utilities, requirement for utility supply voltage stability [16] gives some tolerance on voltage supplied by the electric utility. Without logging voltage over time, it is impossible to precisely determine the power, and thus energy usage of any piece of equipment.

However, if the logged equipment is small relative to the size of the transformer supplying power to it, and if the supply voltage is "stiff,"* it is reasonable to check voltage when the data logger is deployed and use that voltage reading for the energy calculation. If additional voltage readings can be taken when the logger is removed or during the logged period, these can be used to estimate the average voltage. Any assumptions regarding voltage should be stated and justified in the M&V report. Note, it is rarely reasonable to assume that the operating voltage is equal to the nominal supply voltage.

Power factor is a measure that is difficult to obtain without the proper measurement. Because this is a derived measurement, a power meter or power monitor that simultaneously measures current and voltage is required to determine power factor. Without this type of meter, current and voltage measurements can be taken separately but simultaneously, and then the power factor can be calculated, but the math involved is difficult and likely beyond the scope of most M&V technicians. Power meters are available from several manufacturers at prices ranging from a few hundred to several thousand dollars, and at least a simple power meter should be part of any electrical M&V technician's toolbox. It is easy to state that power factor is assumed to be 80% or 90%, but this is rarely correct and can introduce significant error into the annual energy calculation, because power factor linearly influences the calculation. It is sometimes possible to obtain a reasonable estimate of power factor of a specific motor by estimating the load factor and referencing the manufacturer's data sheets for that motor. Motor load, age, and maintenance practices can significantly change the actual power factor from the manufacturer's stated values. A low estimate of power factor is more conservative, and barring any other means to obtain actual power factor, a low estimate should be used.

ENERGY LOGGING

Energy logging began in the late 19th and early 20th century as electric utilities needed a way to charge their customers for the services that they rendered, namely providing cheap, reliable electricity to homes

*Ieeexplore.ieee.org, IEEE Standards Dictionary: "The ability of an area electric power system to resist voltage deviations caused by a distributed resource or loading."

and businesses [24]. Utility grade revenue meters are permanently installed on the electrical service, and provide a measure of energy used. Originally, this meant that a dial would increment as a unit of energy was consumed, and this dial had to be manually read for billing purposes. Modern smart meters can transmit data, which can be read in real time, and have the ability to measure energy, power, and other parameters.

Logging energy "directly" actually means logging volts and amps, and using those measurements to calculate power factor and power, and then calculating energy based on power over time. The energy logger apparatus will include, at a minimum, a current transducer, a voltage lead, and a data logger. On three-phase systems, there will be 3 or 4 sets of transducers and leads, and these can either be attached directly to the logger, or attached to an "integrator box" that does all of the math and sends out energy measurements as "counts" or "pulses." Energy or "kWh" logger sets with Rogowski coils typically use the voltage leads not only to measure voltage, but also to power the Rogowski coil wave form generator circuit, eliminating the need for an external power source. The energy used by this circuit is usually very small compared to the energy being logged, and can therefore be neglected, or compensated for in the energy measurements [23].

This type of logger/transducer can be very accurate over long durations, but can be very inaccurate over short durations. It is common for these transducer sets to have selectable dip switches that can be set to record a "count" or pulse at 1 kWh, 0.5 kWh, 0.25 kWh, or 0.1 kWh intervals. When using this type of device to measure data at 1-minute data intervals the individual data points can be wildly inaccurate.

For example, if a continually operating, fully loaded 20-hp load is logged at 1-minute intervals with a pulse type kWh meter that is set to record 1 pulse per 1 kWh, the data set does not accurately represent the actual energy usage. In fact, the data appears to show that during many of the 1-minute intervals, no energy is used. This obviously is not the case, because we know that 20-hp, or 14.92 kW, is being constantly required. Figure 1 shows the pulse-type meter data overlaid with the actual energy consumed.

The actual energy consumption during each 1-minute interval is 0.249 kWh. For this configuration, the pulse-type meter only increments the count after a full kWh is consumed, so during the first four intervals the reported energy usage is zero. At the conclusion of the 5th interval,

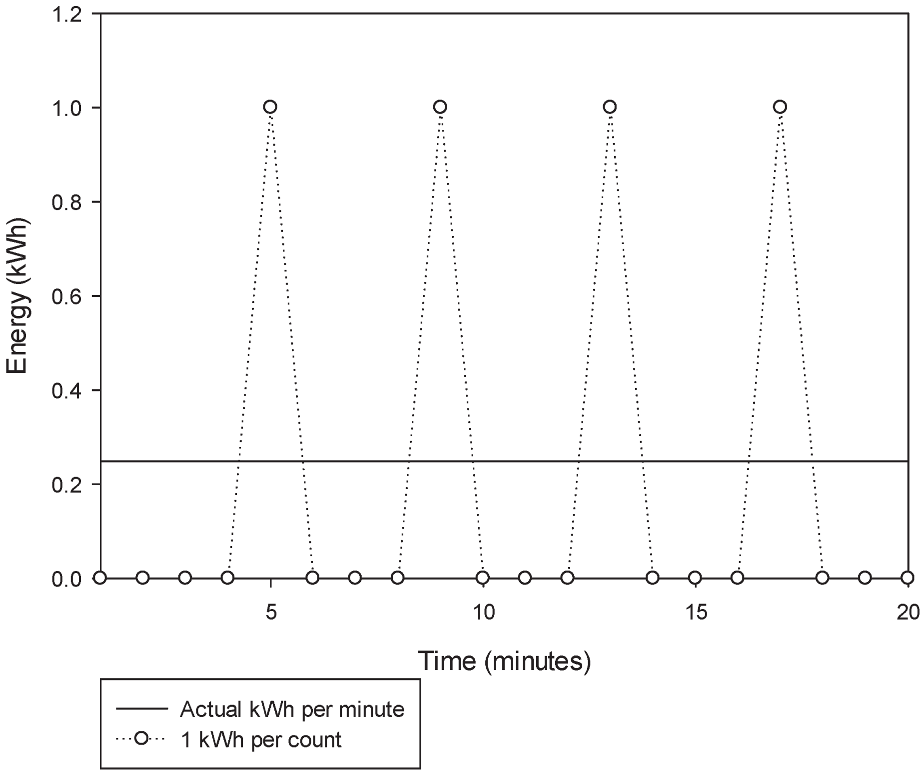


Figure 1. 20-hp$_e$ constant load energy consumption. Actual versus 1 kWh/pulse metered data.

the actual energy usage has been 1.243 kWh, so a count of 1 is recorded during this interval. The 0.243 energy usage is carried over to the next interval, and zeros continue to be recorded until the 9th interval, when the 2nd kWh is consumed and another 1 count is recorded. The process continues, recording 1 count each time a full kWh is consumed.

Many of these pulse type energy transducer sets have the ability to report counts in finer increments. For instance, it is common to see dip switches on the current transformer that allows energy to be reported as 1.00, 0.50, 0.25, or 0.10 kWh per pulse. At the highest setting of 0.10 kWh per pulse, the data for the above case would show 1-minute interval usage of 0.2, 0.2, 0.3, 0.2, and 0.2 kWh for the first 5 intervals. This data is shown in Figure 2.

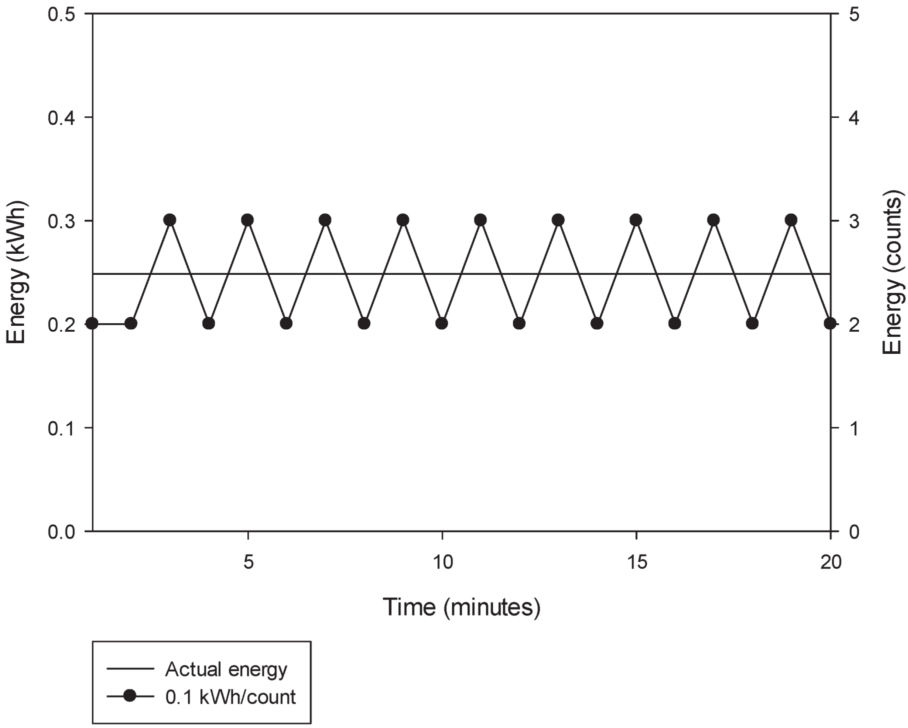


Figure 2. 20-hp constant load energy consumption. Actual versus 0.1 kWh/ pulse metered data.

Because no additional data is recorded by this style of transducer, it is easy to mistake this data for being representative of power over time. If the data above is mistakenly converted from the apparent unit of kWh/minute to kW, the resultant power curves do not accurately reflect the true power being consumed. The three cases are shown in Figure 3.

The 20-hp constant load presented above is provided for illustrative purposes only, and is not intended to represent a real-world example. Let us consider the real case of a 100-hp air compressor being data logged for M&V purposes. This compressor may have a varying load that peaks at around 78 kW when the compressor is fully loaded, and may have a low load condition of around 30 kW when the compressor is idling. This compressor may also shut down on nights and weekends. A possible log of the actual power versus time, in 15-second intervals, over a period of 2 hours is shown in Figure 4.

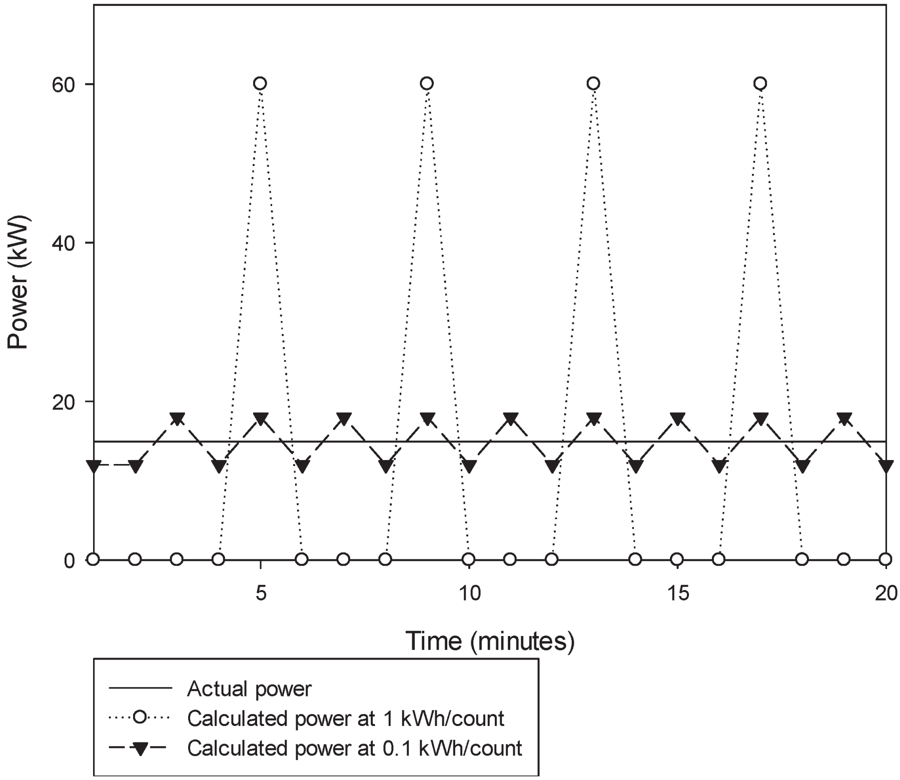


Figure 3. Power versus time for 20-hp$_e$ constant load.

A counting meter, set to record 0.10 kWh per count at the same 15-second intervals, would provide the following data log for the same period (Figure 5).

The energy calculated from the power data in the 2-hour period is 157 kWh. The energy calculated from the pulse-type energy logger is also 157 kWh, showing that over time, the two methods are equivalent. However, looking at 1-minute intervals the story is much different, with the power logger showing an average kW for the first minute of 75.6 kW (which is correct), and the energy logger counting 12 pulses, which is equivalent to 1.2 kWh/minute or 72-kW average power. This is a difference of 4.7%.

Longer time intervals of 5 and 15 minutes can be analyzed to show that the pulse-type meter is more accurate over longer intervals. In the first 5-minute interval, the kW logger shows an average power of 76.1

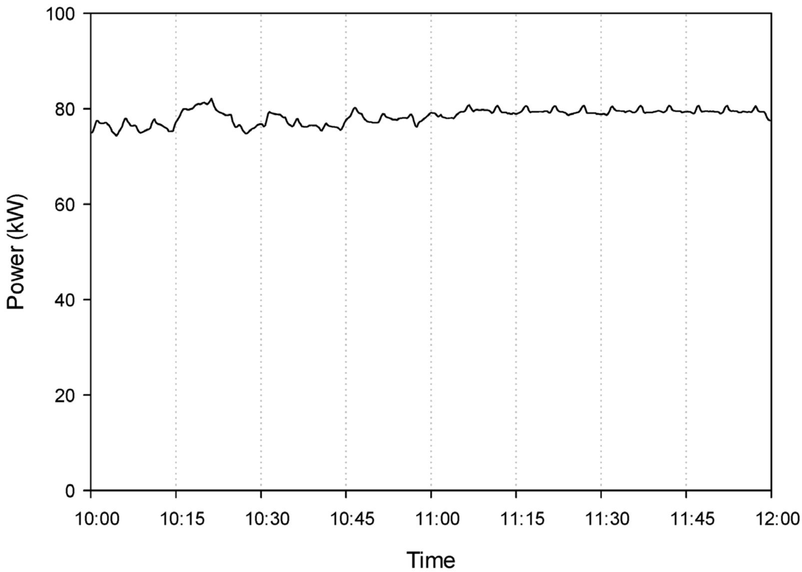


Figure 4. Directly logged power for a theoretical 100-hp air compressor over a 2-hour time period.

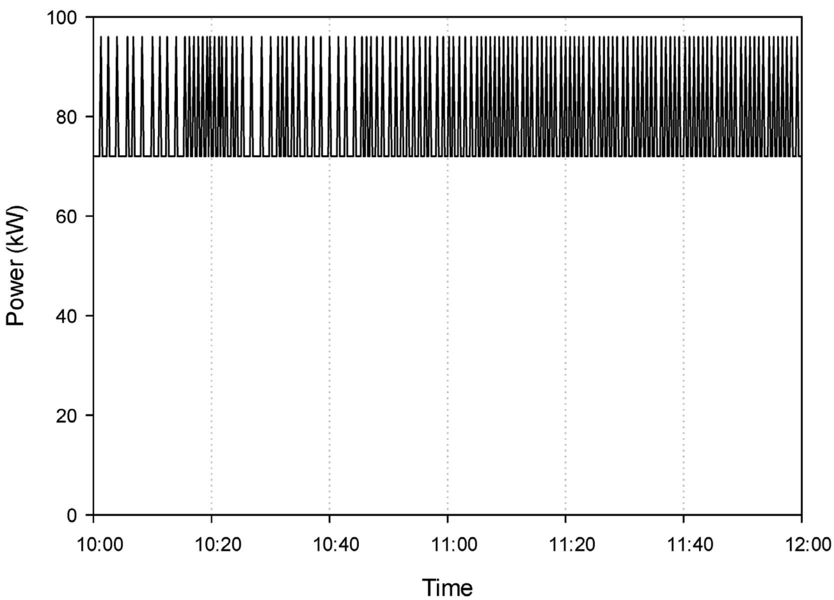


Figure 5. Indirectly logged power data for the same compressor, converted from a pulse type logger recording at 0.1 kWh/pulse at 15-second intervals.

kW, and the pulse meter records 63 pulses, which is equivalent to 75.6 kW, a difference of 0.7%. In the first 15-minute interval (a common utility demand window), the kW logger shows an average power of 76.2 kW, and the pulse-type logger records 190 pulses, which is equivalent to 76.0 kW, a difference of 0.3%. Data for the various logger types and settings are presented in Figure 6 for comparison.

If the data are to be used for simply estimating energy usage over the course of 1-year, the error in each short time interval is inconsequential because the total energy over the logging period is very accurate. If the data are to be used for additional energy auditing and analysis purposes, the short time data provided by a pulse-type logger may provide very little insight and may not be useful to the auditor at all.

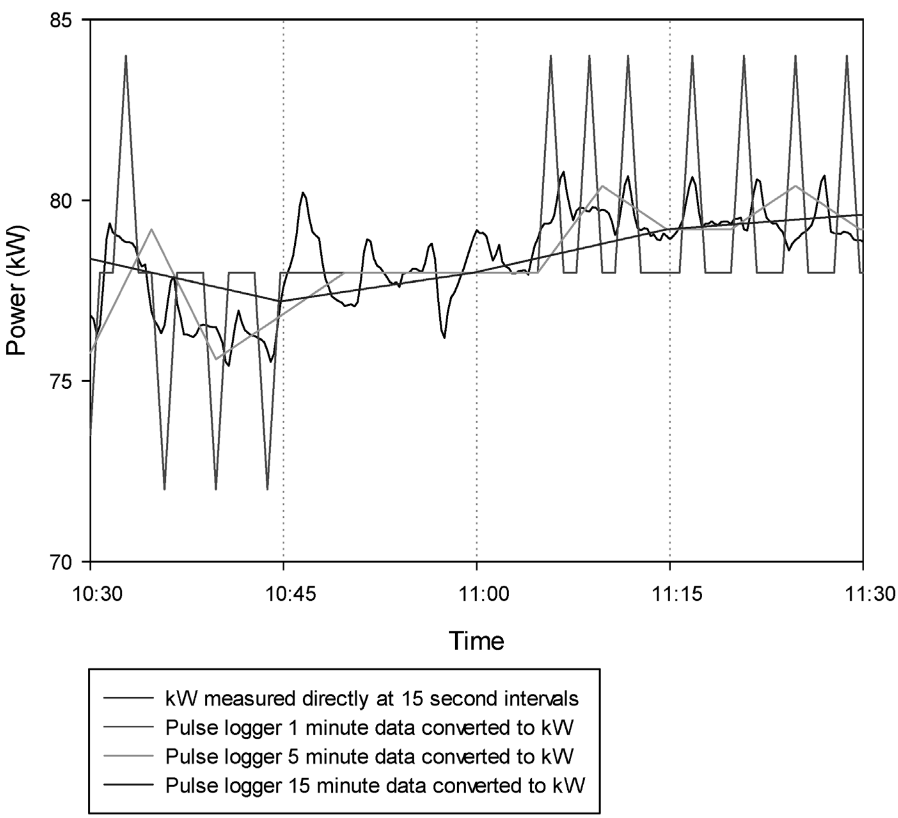


Figure 6. The same data from Figures 4 and 5 overlaid with 5-minute and 15-minute pulse logger data converted to kW. The data period in this figure is 1 hour of the total data from the other figures above.

kW LOGGING

Directly logging power is a third option, which is preferred in almost every scenario, if economically feasible. Power loggers are relatively new, and have arisen as computing power and storage have increased dramatically while costs have dropped in the modern computing era. While energy loggers store kWh readings, power loggers store instantaneous kW readings, as well as kWh and other useful information that is calculated from volts and amps.

The kW logger set up is similar to the kWh logging apparatus, with a current transducer, voltage leads, and a data logger. The exception is that these loggers typically do not have an integrator box or other electronics that are separate from the data logger, so the current and voltage information is logged directly without the use of "counts" or other representative measures. Because power in kW is derived from voltage and current, this type of logger can produce a very accurate representation of power over time as well as total energy used.

Power loggers that can record multiple channels, including measured voltage, measured current, calculated power factor, calculated power, calculated reactive power, and other measures are useful. These loggers have only recently become available, as a result of the memory requirements of logging multiple channels. The benefit is that the actual current over time data is stored in the logger, which is exactly the same as that recorded by a simple current logger described previously, as well as the actual measured voltage over time. This reduces any uncertainty introduced by spot checks of voltage, or assuming a constant voltage.

Because the data points used to calculate the derived values of PF, kW, kVAR, and other measures are stored directly, the data can be much more accurate over short intervals. One tradeoff is that the number of recorded data points is multiplied by the number of channels, so data sets can be much larger and require more computing power to analyze. Modern desktop and even laptop computers should have the ability to handle large amounts of data, so with relatively inexpensive updates to computing hardware this should not be an issue.

Another consideration is that the cost of these modern kW loggers may be many times higher than a comparable current logger. Organizations that perform significant M&V activities should find that this increase in first cost will reduce the long-term cost of data analysis, because all of the relevant data is collected and available.

EQUIPMENT AND DEPLOYMENT COSTS

The logging equipment types described above are rapidly evolving, with data storage capacity and wireless data transfer capabilities increasing dramatically over the last few years. The costs of the individual pieces of equipment may be subject to change, and certainly will not remain constant over time. To the extent that equipment cost factors in to the cost of M&V, several observations are warranted. First, measuring devices are essential for the M&V professional, and while cost is important, no M&V can be performed without these devices. The minimum M&V professional toolkit must include devices that can measure voltage, current, and power factor; or power directly, as well as some type of data logger with the same capabilities. The data logger types discussed above can have a wide range of prices, with current loggers (including small battery powered data logger and current transformer) costing a few hundred dollars, and energy/power loggers costing at least three times as much (since 3 current transducers are required). These costs may be factored into the cost of an M&V plan, if necessary equipment is not available. Additionally, if logging energy or power directly reduces uncertainty, then the purchase of more advanced data logging equipment may be warranted. Because this equipment is durable, the cost of equipment may be amortized over several M&V projects.

The long-term cost of M&V activities should include labor costs, as qualified technicians (such as electricians) must deploy the devices in a safe and effective manner. The cost of M&V activities should also include engineering time, because calculations are required to determine the annual energy usage of the equipment before and after the measure is installed. Table 1 shows the estimated additional cost of M&V activities, using the case where all parameters are stipulated as the lowest cost scenario. In other words, M&V cannot cost less than the case where everything is stipulated and nothing is measured. This baseline (stipulated) also presents the highest amount of uncertainty. The estimates assume that the technician already has basic tools for measuring volts and amps. The cost of purchasing a device to measure power factor and any data loggers is added to the M&V cost for the project. Technician time is estimated as \$50 per hour, and engineering time is estimated as \$100 per hour.

Because measurements are taken on plant equipment, often while the equipment is operating, the time required to obtain any necessary

Table 1. Estimated cost for different M&V activities and equipment. The stipulated value scenario represents the baseline case with no added cost. This does not imply that the activity is free of cost, but that no additional costs are incurred.

Category	Stipulate	Spot check	Current log	Power/Energy log
Equipment cost	-	$900 power meter	$900 power meter + $200 current logger with transducer	$2,500 power logger with transducers
Technician time	-	$50	$100	$100
Engineering time	-	-	$200	$200
Total	-	$950	$1,400	$2,800

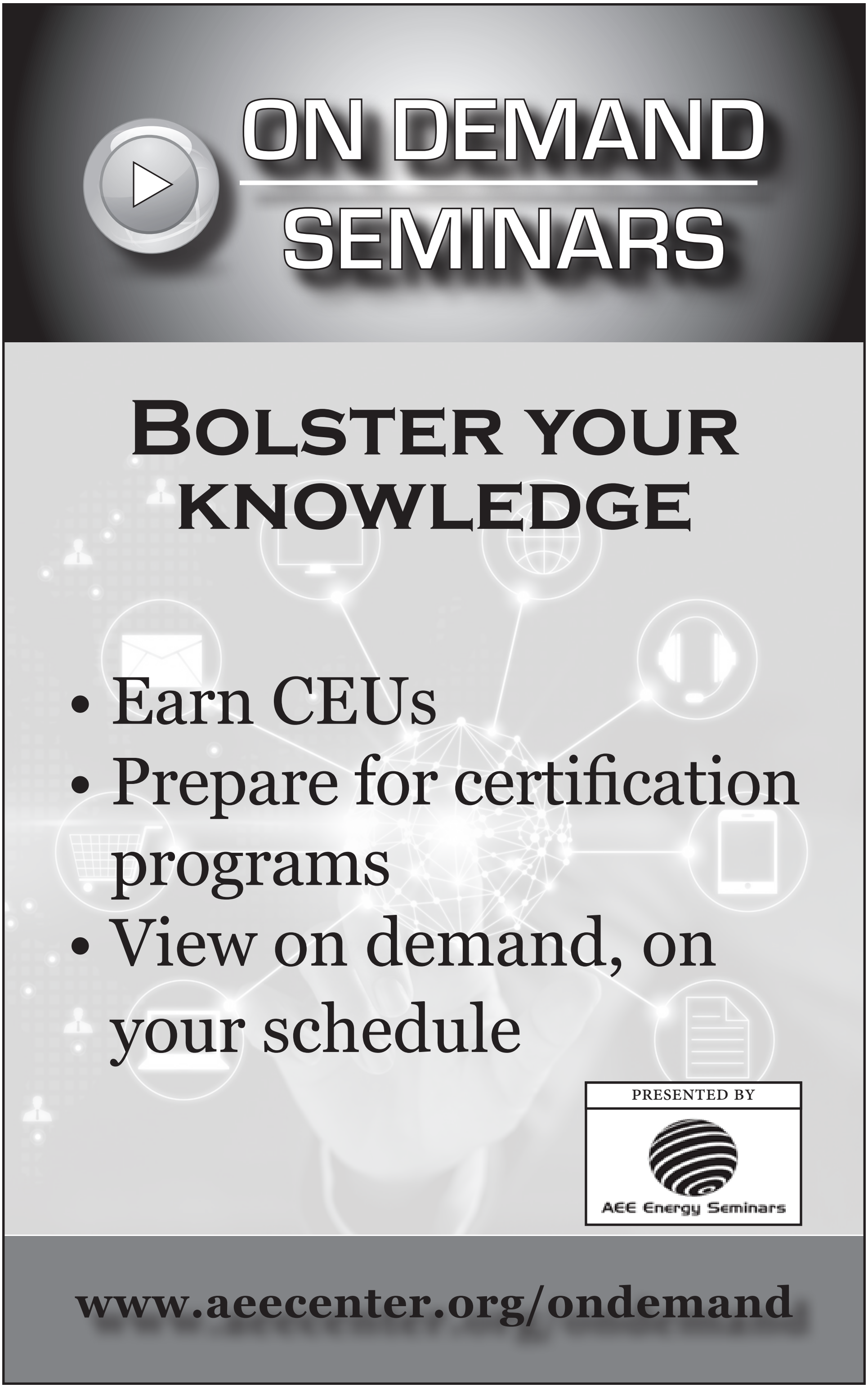
permissions, dress in the appropriate protective gear, open electrical panels or cabinets, and restore the work area to a safe state afterwards can be significant. The actual time to install the measurement device(s) is small in comparison. While it may take substantial planning to schedule and prepare for a data logger installation, the actual installation typically only takes a few minutes. This is true for spot checks, single-phase current logging, and three-phase energy/power logging alike. In Table 1, this is estimated as 1 technician labor hour to perform all of the necessary functions to acquire one spot checked power measurement. Assuming that the technician did not already own a power meter, this activity would cost $950 more than stipulating all parameters, but may reduce the additional uncertainty by a great amount.

The cost difference between spot checking of measurements and deployment of data loggers, from a labor perspective, results from the need for the data logger to be both deployed and be removed once the logging period is complete. Again, the time to actually remove the device is very small in comparison to the time the technician must take to do it safely and properly.

Engineering calculation also requires some minimum, or baseline, amount of time and effort regardless of the method used to determine the parameters. Stipulating all of the parameters, therefore, represents the zero added cost scenario. Spot checking of measurements provides single values for the parameters (such as volts, amps, etc.), so the calculation time for this scenario is similar to stipulation of parameters. Data logging typically requires analysis of large data sets, which can take several hours to several days, depending on the amount of data. For the purpose of comparison, a single measure project with a single data logger deployment should generate a single data set, which may take two hours to interpret. In Table 1, a scenario where one current data logger is deployed would cost an estimated $1,400 more than the case where all parameters are stipulated. The case where one power logger is deployed would cost $2,800 more than the case where all parameters are stipulated.

These estimated additional costs can then be used, along with the estimated additional uncertainties presented previously, to determine which M&V method is most cost effective for a particular energy efficiency project.

As an example, consider a compressed air project with an estimated savings of 100,000 kWh annually. At $0.10/kWh, this represents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an annual savings of $10,000. Stipulating all parameters may have additional uncertainty that is very high. Simply stipulating operating hours can add 30% uncertainty to the savings estimate, or $3,000, which should rule out stipulation of all parameters as well as spot checking, which requires stipulation of operating hours. Data logging current requires that voltage and power factor be spot checked, which adds 16.5% to 22.9% additional uncertainty, representing up to $2,290, for a cost of $1,400. Logging power (or energy) reduces additional uncertainty to zero, for a cost of $2,800, or about $1,400 more than logging current. In this case, logging power directly reduces uncertainty by $2,290 for a cost of $1,400. Determining if the benefit is worth the cost is left to the reader, recognizing that the cost of purchasing some of the required equipment might be neglected or amortized over several projects.

CONCLUSIONS

Measurement and verification of energy savings has been and will continue to be an important activity for energy managers, government agencies, building owners, and utility representatives. Understanding the M&V process, the importance of the M&V plan, the limitations of the M&V equipment, and the process of determining energy savings are keys for a successful energy efficiency project.

M&V plans should follow the IPMVP framework, taking into consideration the cost of M&V activities and the potential reductions in uncertainty related with different levels of M&V. Estimates and judgments should be sufficiently conservative with regards to the accuracy of the M&V methods that are specified.

Finally, logging electrical data as part of IPVMP option A and option B M&V plans can be accomplished with several available styles of data loggers, and each of these styles has advantages and limitations. Current loggers are inexpensive, but care should be taken to measure voltage and power factor appropriately. Pulse style energy loggers can provide simple long-term measurements of consumed energy, but should not be used to collect short-time interval data, because their accuracy in short intervals can be poor. Loggers that measure and record current and voltage, and then calculate other measures such as power factor, power, and kVAR are more expensive, but can provide accurate data for both short and long intervals.

Understanding these complex but necessary concepts can provide a high degree of confidence in energy savings projects.

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Virtual Audits: The Promise and The Reality

John M. Avina
Steve P. Rottmayer

ABSTRACT

A good energy audit is a valuable owner's guide to making the best energy efficiency investment decisions. When the best energy conservation measures (ECMs) are identified and implemented, the facility owner will make the smartest choices, and receive the greatest return on investment. When the best ECMs are not identified and implemented, then the opportunity for reducing utility costs has been squandered, and the facility owner suffers financially as a result. Traditionally, developing energy audits involved hiring professionals to identify and communicate the ECMs. Typically, the more seasoned and skilled the energy auditor, the better the energy audit.

With the advent of advanced databases and the availability of electricity interval data, new software and services are now available that provide some impressive analysis of building energy usage. One of these new services, virtual audits, often offer inexpensive energy audits, attractive web graphics and the capability to provide fast analysis of individual buildings as well as aggregates of buildings without an energy auditor having to set foot on site.

The question addressed in this paper is whether these companies that provide virtual audits are making claims that are unsupported. The main claim is that a virtual audit can produce an actionable energy audit without having an energy auditor set foot on site. This article endeavors to evaluate these potentially overreaching claims by considering the differences between traditional and virtual audits.

THE PROMISE OF VIRTUAL AUDITS

Analytics-based audits, or virtual audits, fill a market need, as energy audits can be perceived to be expensive. The high price of an energy audit often serves as a bar, preventing many facility owners from having them done. A traditional audit might cost between $8,000 and $30,000 for a 500,000 square foot office building, depending on the level of detail. The auditor might spend one or many days on site, and would require hours of the facility staff's time, which itself costs money.

Several companies are now offering virtual audits which can dramatically cut the number of engineering hours and cost associated with performing an energy audit. These virtual audits are mostly being used by utilities and the federal government (which has tens of thousands of buildings).

The claim is that virtual audits provide useful energy audits without having to send energy auditors on site to evaluate the building. These audits require only electric interval data, gas bills (which are optional), and the address of the building. These virtual audits are relatively inexpensive and sell for a fraction of the cost of traditional audits. In addition, virtual audits do not tie up busy facility staff for hours. The virtual audits may be presented on a web portal with attractive graphics, good utility usage analysis, benchmarking, and even measurement and verification capacity.

To evaluate the effectiveness of a virtual audit, we must first define what a good energy audit is.

WHAT IS A "GOOD" ENERGY AUDIT?

Energy audits can take a multitude of forms, and whether the audit is "good" depends on the goals of the project. With the different goals in mind, ASHRAE (the American Society of Heating, Refrigerating, and Air-conditioning Engineers) has defined three energy audit levels. ASHRAE Level 1 audits provide an overview of the building and give guidance toward areas of inefficiency. A Level 1 audit includes a list of measures, but does not provide energy savings or costs for each measure. ASHRAE Level 2 and 3 audits are much more detailed with the goal of providing the facility owner with an actionable plan that can be used to reduce energy use at the building. Table 1 lists the report deliverables associated with the different levels of energy audits based on the ASHRAE Procedures for Commercial Building Energy Audits.

Many companies that sell virtual audits claim to provide detailed audits that enable the user to immediately start work with a contractor to begin implementation. Based on Table 1, this is, at minimum, an ASHRAE Level 2 audit, which is what we consider a "good" audit. So what should be included? First and foremost, the audit should include a comprehensive list of energy conservation opportunities that provides a clear description of what needs to be done. Each of the efficiency measures needs to describe:

- What is the problem
- Which units are affected
- How does it waste energy
- How should it be remedied
- How much energy and costs can be saved
- How much will it cost to implement the ECM
- Financial metrics to evaluate the ECMs against each other.

Table 1. ASHRAE Audit Deliverables

Deliverable	ASHRAE AUDIT LEVEL		
	1	2	3
Estimate savings from utility rate change	Yes	Yes	Yes
Compare EUI to EUIs of similar buildings	Yes	Yes	Yes
Summarize utility data	Yes	Yes	Yes
Estimate savings if EUI were to meet target	Yes	Yes	Yes
Estimate low-cost/no-cost savings	No	Yes	Yes
Calculate detailed end-use breakdown	No	Yes	Yes
Estimate capital project costs and savings	No	Yes	Yes
Complete building description and equipment inventory	No	Yes	Yes
Document general description of considered ECMs	No	Yes	Yes
Recommend measurement and verification (M&V) method	No	Yes	Yes
Perform financial analysis of recommended ECMs	No	Yes	Yes
Write detailed description of recommended measures	No	No	Yes
Compile detailed ECM cost estimates	No	No	Yes

In addition, the energy audit will consider whether the recommended measures can be implemented, and whether the measures are cost effective. For example, if a mechanical room is already too full, additional equipment cannot be added to the mechanical room, and this may necessitate building another one. Another example, if natural gas service is not available on the rooftop, natural gas lines will need to run to the new package units that are being recommended.

Level 3 audits include a detailed scope of work so the contractor who implements the efficiency measure will know exactly what to do. The scope of work describes clearly what the contractor must and must not do when implementing the measure. The scope of work will prevent the contractor from

- repairing/replacing the wrong unit,
- repairing/replacing too many units,
- installing the unit but not providing appropriate control strategies to ensure that the units save energy
- adding on additional unwanted services and equipment.

Having defined the objective of a "good" detailed audit, let us examine the virtual audit approach.

HOW THE ANALYTICS MODEL WORKS

Although their marketing material may stress the value of analytics, the new developments in computer power and the successful utilization of interval data, the methods employed by these companies rely heavily on an off-site survey that is similar to a telephone audit. Using a question and answer format, they seek to uncover energy efficiency opportunities. For example, "are you currently employing a chilled water reset?" If the answer is no, then an ECM has been found, a chilled water reset.

Virtual audits use a question- and answer-type process with facility personnel to uncover ECMs, and then often use interval data to back up the findings from the dialog. Sometimes the interval data may point to issues independent of dialog. The dialog may be in the form of an online survey or a telephone survey. These surveys ask many questions about the facility including: construction type, age of facility, occupancy hours, building automation system (BAS) type, age of BAS, what control strategies are in place, etc. Certainly these types of phone calls or surveys can be useful and can identify energy savings opportunities. Easy to identify opportunities might include: equipment scheduling, night setbacks, lighting retrofits, and some control strategies.

Analysis

Virtual audits employ software to analyze 15-minute electric interval data. The software uses sophisticated algorithms, often with assistance from a person, to break out utility usage into end uses, such as lighting, pumping, Heating, ventilating, and air conditioning (HVAC) fans, etc. The software can also point to potential ECMs. The model can easily identify some potential areas of waste, such as lighting and HVAC schedule problems, as well as inefficient lighting or cooling.

The model produces an output that is then interpreted by an energy engineer, who digs deeper into the data to find more potential measures, and disqualify any that the model inappropriately recommended. During this stage, the energy engineer may also contact the facility manager or engineer to talk through questions that present themselves.

Measure Review

Once an analysis has been completed, and a list of measures has been created, the virtual auditors meet with the client (usually in a web conference) to discuss the measures found and the next steps the client should take.

Implementation

After the measures are presented, it is suggested that the client call an appropriate contractor to implement the measures. The contractor will determine counts of equipment to be replaced, or in some cases, the exact issue(s) causing the excessive energy usage, and will then put together a proposal and price to remedy the situation.

STRENGTHS OF VIRTUAL AUDITS

Analytic software, with their sophisticated algorithms, is a powerful analysis tool. Through the use of this tool, virtual audits have some significant strengths.

Cost-Effective Analysis of Large Data Sets

The data available to analyze facility energy use has increased significantly in the last decade and continues to increase as the cost of monitoring, storing and analyzing data decreases. The list of useful data includes:

1) Interval energy and weather data that can be used to gain insight into the daily operation. Sub-meters at facilities further enhances this insight.

2) Databases (Energy Star, CBECS*, etc.) containing a breakdown of the typical facility end use, grouped into standard building categories, can help identify areas of inefficiency to target.

3) Databases of past energy efficiency projects, such as the Database for Energy Efficient Resources (DEER), containing typical savings and costs for specific measures that can be used to help create measures.

The existence of so much data provides an opportunity to improve the value of energy audits, but it also presents a problem because it becomes more and more difficult to incorporate data into the analysis. Effectively identifying the patterns and anomalies in all this data takes a person longer and longer and becomes less and less possible. In summary, analyzing buildings has started to become a big data† problem.

Analytic tools provide the best means of cost-effectively finding the patterns present in that data. Analytics are now used in many industries including financial, retail, and even sports. Utilizing this powerful approach makes sense for energy efficiency as well.

Presentation of Data from Multiple Buildings

Most, if not all, customers of the virtual audit companies are responsible for a large portfolio of buildings. Trying to review and track

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*Commercial Buildings Energy Consumption Survey (CBECS), a publication of the U.S. Energy Information Administration (EIA), http://www.eia.gov/consumption/commercial/

†Big data, as described by Meta Group (now Gartner) in a 2001 research report, refers to large data sets that are so complex that traditional data processing techniques do not work. Although energy auditing may not quite be on the level of say analyzing social media, more and more it appears to be heading toward that level of sophistication.

energy efficiency projects from a stack of separate reports is difficult and time consuming, if not outright impossible. Virtual auditing tools compile the virtual audit report data into one powerful interface that provides managers an easier method to review and track the ECMs and energy usage characteristics of their portfolio. Imagine having one thousand buildings to track, and being able to see an aggregate energy balance, which breaks out energy usage into lighting, cooling, etc. These web interfaces can also report the frequency of ECM types, which types of buildings or regions are associated with different ECMs, etc. The information presented on these tools helps managers prioritize sites, track projects and evaluate the results.

Potential Issues are Highlighted

Most facility personnel are very busy and have very limited time and resources available to spend with energy auditors. Rather than spending hours walking on site, auditors around the building, an online survey or telephone survey with the virtual auditors provides a quick and easy method to convey information about the building. This survey then helps the virtual auditors understand the building remotely so they can interpret the analytics model and identify areas that need attention such as:

- Equipment operating more hours than necessary
- Outside air economizers not functioning optimally
- Simultaneous heating and cooling is occurring.

Although there are many possibilities of causes, simply identifying the problems can help improve the cost-effectiveness of any follow-up analysis.

Straightforward Measures are Identified Quickly

Energy efficiency is one of many responsibilities under the purview of facility operators. And given the relatively low cost of electricity compared to the cost of empty floor space or lost production, energy efficiency is typically a low priority compared to safety, comfort and maintenance. This leads to situations where even straightforward measures are overlooked.

Recently, when we were presenting a list of ECMs to a facility manager, we suggested that they schedule their air-handling units (AHUs), because the AHUs were running all weekend conditioning an empty building. The manager angrily told us that we were wrong, that this was his building, and that he knew the AHUs ran only during weekdays. We showed him pictures of the BAS scheduling screen proving that that the AHUs had been scheduled to run all night. The facility manager, as it turns out, had not looked closely at the controls for years, because he had been promoted to manager for a few sites. All along the facility crew that now runs the building had been overriding the schedules and set-points he had set years ago. This was a case where the facility manager used to know how the building operated, and he thought he still did know. A survey alone would not have caught that measure, but coupled with analytics, and diligent follow-up with site staff, this measure likely could have been identified without time spent on site.

SHORTCOMINGS WITH VIRTUAL AUDITS

Although analytics are a powerful tool, using this approach exclusively to replace traditional audits has significant weaknesses.

Problems with the Survey/Interview

A critical component of the virtual energy audit is the survey. In a typical survey a facility manager (or operator) answers a questionnaire, either online or by phone, about the building energy using systems. The questionnaire is relatively short, covering the major characteristics of the main end-use systems*. There are many shortcomings with this approach:

1) Many Important Follow-up Questions Get Left Out

The surveys do not always identify the distinctive characteristics of buildings and their energy-using systems. Buildings are often so unique that it is impossible to identify all of the important questions to ask in advance. Often the answer to one question leads to another question. For example:

*For the traditional energy audit process, this same step is taken, however, in the form of a live interview. But typically, after the equipment and BAS have been inspected, the auditor has a series of follow-up questions either to gain more information, or to handle inconsistencies between the interview and what the auditor found in the field.

How is your data center cooled?

It is cooled by computer room air conditioner (CRAC) units and AHUs.

In the winter, which does most of the cooling? The CRAC units or the AHUs?

The CRAC units. The AHUs only provide ventilation.

Do the AHUs bring in 100% outside air?

AHU-1 does, but AHU-2 does not, because we had problems with humidity.

So AHU-2 has a damper that modulates the amount of outside air?

No, it is bringing in a fixed amount of outside air, maybe 10%.

And the AHUs are delivering air to the ceiling of the building?

No, AHU-1 delivers air into the underfloor area, AHU-2 delivers air to the battery room and other auxiliary areas.

Oh, and the size of the motors?

Well, we reshived AHU-1 so that it now delivers 30% of its original CFM.

Why did you do that?

To save energy. We had to dehumidify the hot air in the summer and to humidify the cold air in the winter. This way, with less outside air, we were able to avoid that.

The CRAC units, they have their own compressors right?

No, they get chilled water from the chillers.

So much complication! But many buildings are unique in this way. In this example, the survey would likely have missed:

- that one AHU is delivering air underfloor
- that one AHU was reshived
- that the CRAC units were actually computer room air handler (CRAH) units
- that they were having problems with humidification.

Because buildings are complicated and unique, the survey-based approach often cannot gain a complete understanding of the building, nor consequently of the ECM opportunities. Furthermore, an online survey that attempted to capture all possible scenarios would become exceedingly long, tedious and unlikely to be completed. An experienced auditor is able to guide the process efficiently to correct possible errors and identify unique situations.

Energy audits are an inherently iterative process. First there is an interview of the facility operator, then an inspection of the BAS and the energy-using equipment. Typically, there will be another discussion with the facility operator as new questions arise that need to be answered.

For example, we recently audited a strange building that had very large internal cooling loads, and required cooling at all times. In the winter the chillers were turned off, and outside air was used to cool the building through economizers on the AHUs. However, some areas were cooled by fan coil units that did not have access to outside air for cooling. Rather than have the chiller produce chilled water for the fan coil units, the outside air dampers for the AHUs were fully open, and chilled water was created from the cold ambient air using the cooling coils inside the AHUs. The AHU supply air heated some in the AHUs, and then reheated in the zonal variable-air volume (VAV) boxes. Would an off-site survey uncover this type of operation? Even a single phone conversation might not uncover this one, because the facility operators did not think to mention this until we had analyzed the BAS and started asking additional questions.

2) Facility Managers Limited Availability

Most facility personnel are very busy, which is a negative when relying on a site survey. There are always more projects to undertake and problems to solve than they have time for. These overburdened facility personnel often address the energy audit as quickly as they can. For some projects, we have sent out pre-site visit questionnaires, and we have seen questionnaires returned nearly blank, with very little effort taken. When the energy auditor is there in person, it is easier to get the attention of facility operators. The facility operator is able to respond to a real person asking questions, and the survey is followed by a tour of the site.*

*Sometimes facility operators will not even participate in this step and this should make the auditor question the likelihood of any measures actually being implemented, which is usually an even more labor-intensive process.

When the audit involves an online survey, there will be many facility managers who will answer the survey as quickly as possible, and in their hurry, may either misinterpret questions, or skip the questions that require more time. If the survey is too long, the facility manager will be less likely to complete it. If the survey is too short, less building information can be collected.

3) No Independent Confirmation that the Survey is Accurate

The other problem with online surveys and telephone-based assessments is that the facility manager's description is not verified by actual observations. As every seasoned auditor knows, facility operators' understanding of their buildings varies greatly. Some are very knowledgeable, having worked at their building for many years, and (we) energy auditors are happy to learn from them; but many are not intimately familiar with their building because they are new or too busy to stay on top of all the changes.

The on-site survey often identifies mistakes from the interview and, in some cases, exposes an engineer trying to conceal their inexperience or lack of knowledge.* We have run across facility operators giving the answers that they think we want to hear by guessing and, in rare cases, outright lying. After the in-person interview about the energy-using systems, we then inspect the BAS and the HVAC equipment, and that is where we find out how accurate the facility manager has been. How is an online survey or a telephone audit going to determine the accuracy of the answers? An analytics-based energy audit is highly dependent on the assumption that the answers accurately represent the building. In a large percentage of buildings, this is just not so.

One common problem with military bases is that the facility operators or mechanics rotate every 2 or 3 years. On military bases, the facility operators often have many buildings to maintain, and never get the time to actually learn how they work. Many of these facility operators do not know their systems.

We have run across many buildings where the person who knew the systems had just retired; in fact, that is why management decided to get an energy audit. There were no drawings of the buildings, sparse records

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*It is not the intent of an energy audit to tell management that their facility staff is either incapable or ignorant of how to efficiently run a building, but sometimes it is perceived that way. The industry's use of the term "audit" probably does not help.

of all the renovations, and nobody knew anything about the HVAC.

In either of these cases, who is going to answer the survey? What value will they be able to provide? An analytics-based audit would likely offer very few suggestions for energy efficiency.

In sum, when the majority of the data collection associated with the virtual audit is associated with an online survey or telephone call, there is a great likelihood that the collected information will not give an accurate representation of the building and its energy-using systems. The problem with this method of data collection is that the virtual auditor will need to rely on the facility operators, who may not know the information, or may not take the time to provide accurate and complete answers. This can be compounded by someone who may guess or provide outright false information. If the virtual auditor's knowledge of the building is based on inaccurate or incomplete information, how is the virtual auditor to develop a list of ECMs appropriate for the building?

Issues with Identifying Which Items are Problematic

Another issue with a virtual audit is the likelihood of false positives and misdiagnoses. Suppose that an analytics based energy audit identifies that there is not enough free cooling being utilized in the building. Although this is useful insight, there are still many questions that need to be answered concerning the root cause of the problem. Could it be that:

- The ducts are too small to allow in sufficient outside air?
- The economizer dampers are rusted in place?
- The damper linkages are somehow faulty?
- The actuators are broken?
- The pneumatics have been disconnected from the actuators?
- The economizer programming is faulty?
- The economizer setpoints in the BAS have been overridden?
- The outside air temperature sensor is not reporting?
- The BAS is not communicating with the AHU controllers?

It could be any one or several of these root causes. Each of these different issues would lead to the economizers not providing free cooling. The range in costs for addressing these issues goes from virtually free (resetting the overridden control point) to prohibitively expensive (the ducting is too small to provide sufficient outside air). A remote audit could not make that determination, and this is where the added expense of a traditional audit provides real value.

Furthermore, it is not unusual for a large building to have 50 AHUs. Suppose a large number of these AHUs have economizer issues, and that the virtual audit is able to identify that there is insufficient free cooling. Not only will the remote auditor not know what types of economizer issues need to be addressed, the remote auditor will not even know which of the 50 AHUs have economizer issues. How is the virtual audit going to cost this measure when they do not know what has to be repaired, nor how many units need work done on them?

Issues with Identifying the Root Cause of the Problem

Analytics is often able to determine whether a facility is using too much energy for cooling. Although the analysis shows that the cooling system is inefficient, it is doubtful whether the remote auditor can determine exactly what is causing the problem. The following root causes can lead to excessive cooling usage:

- Low chilled water setpoints
- Low zone temperature cooling setpoints
- Low AHU supply air temperature setpoints
- Open windows in summer
- Oversized supply fans
- Too much outside air
- Undersized cooling tower
- Excessive fouling in cooling tower fill
- Poorly performing cooling tower
- Inefficient chiller
- Building operator overrides on condenser water, chilled water, AHU and/or zone setpoints
- Poor chiller staging
- Chilled water leaks
- Leaking preheat coil valves along with no boiler lockout
- Stuck chilled water valve
- No communication between BAS and AHU controllers
- Uninsulated chilled water pipes.

And there are many more possible reasons.

Some of the problems listed above can be identified during an interview with the facility manager. Many others, though, can only be identified by someone who is on site.

Limited List of Measures

There are some measures that are nearly impossible to identify with only interval data and an off-site survey. Someone really needs to see the problem with their own eyes. The list of these possible measures is actually quite long and only a few are listed here.

- Temperature sensors out of calibration or poorly placed
- Poorly programmed control strategies
- Stuck chilled water or hot water valves
- Daylighting
- Data center measures such as isolating warm aisles and cool aisles
- Replacing/repairing iced over compressors
- Water or steam leaks
- Missing ceiling or underfloor insulation
- Disconnected pneumatics, compressed air leaks
- Fume hood leaks
- Uninsulated chilled water, steam or heating hot water piping
- Throttled chilled water or heating hot water loops
- Inefficient kitchen equipment
- Strip curtains, door closers, electronic commutated motors and evaporator controllers in walk-in coolers

We have seen three virtual audits point, and they had three, three, and six ECMs identified in the reports. In contrast, when we perform energy audits, we typically have a difficult time keeping the number of ECMs under 15, and have turned in reports with over 30. Providing a comprehensive list of measures is a critical component of any audit. Because an energy auditor is not on site, virtual audits cannot produce a comprehensive list of ECMs.

Poor Measure Descriptions

ECM descriptions in virtual audits are notoriously short. A typical ECM description will have one or two sentences. These descriptions are likely short because there is not enough detail known to provide fuller ECM descriptions. Many types of information are missing: what equipment is to be installed, a description of the sequence of operation to be programmed, and which pieces of equipment need to be addressed (i.e., which lights, which AHUs).

The short ECM descriptions can lead to improper implementation of the measures, which can severely hurt return on investment. A simple example may be "Replace fluorescent lighting LEDs." This would be a good measure, but if the object of the energy audit is to cost effectively reduce expenses, then the fluorescents should only be replaced in those areas where lights burn thousands of hours each year. Janitor closets, mechanical rooms, and abandoned spaces should probably keep their fluorescents, because it is not cost effective to replace the fixtures. Because they are used so rarely, they most likely will not burn out any time soon.

Another example might be: "Install occupancy sensors in office spaces and restrooms." On the surface, this measure is a good ECM. However, there are some hidden problems associated with this measure. Occupancy sensors will not operate properly with instant start ballasts. The 20,000-hour lamp life can be shortened so dramatically, that the additional operations and Maintenance (O&M) cost of replacing burned out fluorescent tubes can become greater than the cost of the energy savings. This information is not given in the virtual audits. In addition, depending on the cost of electricity, occupancy sensors are only cost effective when there are several fixtures on one occupancy sensor. Many private offices would not be cost-effective choices for occupancy sensors. But the virtual auditor would not be able to identify which spaces should have sensors installed.

Inaccurate Measure Pricing

Accuracy in estimating energy savings is important in an energy audit, but what is often overlooked is that accuracy in pricing the ECMs is equally important. Often what really matters when determining which ECMs to implement is some financial metric, such as simple payback or life cycle cost. These financial metrics are calculated using both energy savings and costs. For accurate financials, you need accurate energy savings and accurate costing.*

To determine accurate costing, the auditor must know what exactly

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*If all that mattered was energy savings, then an energy audit would need only recommend an off grid solar photovoltaic (PV) system for every building. Then all electricity can be saved. There would be no point investigating complicated HVAC controls measures. The reason these systems rarely make it into energy audit reports is the poor financials associated with off grid PV, especially when compared to retro-commissioning and other energy efficiency retrofits which are more than three times financially attractive than off grid PV.

needs to be repaired, replaced or installed, and how many units need to be addressed. As we have already stated, a virtual audit cannot provide this information. Instead of providing a good estimate of costing, virtual audits provide a cost range. In our previous example about economizers, the cost range would be between releasing BAS overrides of outside air % (perhaps $25 each) to replacing rusted dampers (up to several thousand dollars each). Still worse, in this building of 50 AHUs, how many of them need to be addressed? The cost range for this example can range from a few hundred dollars to tens of thousands of dollars. Wide cost ranges like this render the financial metrics of little value to the facility owner.

Even assuming that the remote audit team can identify the equipment that needs to be replaced, if the remote audit team has never been on site, how will they be able to estimate costs of piping, the costs of demolition and removal of old equipment, the costs of placing new equipment into mechanical rooms? To reasonably price an efficiency measure, the energy engineer must know constraints that will affect the cost. These constraints include:

Access: Some mechanical rooms can only be reached through narrow hallways, or after climbing or descending stairways. Occasionally a boiler may have to be either mothballed in place, or cut into pieces before being hauled out. Sometimes new enclosures have to be built to house the new equipment.

Energy Supply: Some roofs (or even buildings) do not have natural gas lines, and must have the lines installed. Some electrical panels cannot handle the current required to implement electric domestic hot water, or electric reheats. These costs need to be integrated.

Controls Integration: It is important to understand the existing HVAC control system to determine how new equipment will be able to connect to it. Sometimes, special drivers or controllers are required to connect new equipment to the control system. This adds extra cost.

The authors hope that we have conveyed the difficulty of attempting to cost the ECMs identified in a remote audit. Again, how is the client to know whether the ECM is cost effective if there is no reasonable price estimate for the ECM?

Construction Contractors Are Not Energy Experts

One analytics company once explained to us that after a problem is found, then the client would pay a contractor to identify the underlying issues, provide a quote, and then implement the remedy. For this reason, there is no need to provide specific ECM descriptions because the contractor, an expert in his field, will determine what needs to be done.

Ask any energy engineer with a decade or more of experience, and he will tell you that most contractors are not trained to identify and implement energy conservation measures. They do know how to install a specific piece of equipment and how to make it work; however, they need the details on how to make it work efficiently. In the aforementioned case, where a virtual audit identifies excessive cooling usage but is unable to identify the problem, a chiller contractor might recommend a new chiller, a controls contractor might recommend new controls, etc. Contractors are typically not the right people to identify energy efficiency strategies. They are very knowledgeable about their field, often knowing more in their specialty than the energy auditor, but their area of expertise is narrow. Someone is needed with a building-wide, systematic approach who takes into account all of the systems. Only then can the problems be identified and remedied. This is the job for someone with experience in energy efficiency and auditing, which is not a typical contractor.

CONCLUSIONS

Although data analytics can be a powerful tool, there are still a number of reasons why traditional auditing methods are still necessary. One of the biggest weaknesses of virtual audits (and poorly done traditional energy audits) is that the best ECMs are usually missed. This has two negative impacts. First, the facility owner will focus valuable resources on measures that are not going to provide the best results. If the facility owner plans on acting on the virtual audit recommendations, when the best ECMs are overlooked, the facility owner will end up investing in second-tier solutions and receive less return on investment. Second, the facility owner may be left with a sense that their building is actually quite efficient with limited opportunities to save energy. The owner is, in essence, leaving money on the table by not implementing ECMs that a sub-par audit did not properly identify. Virtual audits, in their current form, will likely perpetuate these problems.

The inability of virtual audits to specify accurate estimates of energy savings potential or costs to install ECMs contributes to audits of questionable value. Virtual audits can identify some ECMs, but cannot accurately estimate the energy savings or costs, because the specifics of the problem at hand are not known, such as counts of equipment to replace, the true nature of the problem, and implementation difficulties that add to cost. So savings and cost estimates are given as a range of values instead. This inaccuracy makes it difficult for the facility owner to determine which ECMs would be cost effective to implement, again with the result that, the facility owner, heeding the advice of the audit may end up implementing ECMs with high simple paybacks, while those with low simple paybacks are overlooked.

Although virtual audits can be a valuable aid, these audits cannot, as of yet, replace an experienced energy auditor. Revisiting the ASHRAE deliverables shown in Table 1, virtual audits do complete the ASHRAE Level 1 tasks, but there is a high probability that a virtual audit will miss a large number of cost-effective energy efficiency measures, that even a traditional ASHRAE Level 1 audit would provide. The virtual audits that we've seen certainly do not provide an ASHRAE Level 2 or Level 3 audit. With this in mind, care should be taken not to overreach and strain tool credibility. These overreaching claims not only hinder the use of other good products, but damage the customer's perception of the value of an energy audit, and harm the customers, who are left with an incomplete analysis, and consequently end up making poor energy efficiency investments, and missing opportunities for reducing utility costs.

An energy audit, by definition, provides expert guidance so that the facility owner makes the best energy efficiency investments. If the energy audit provides poor guidance, and the owner is misled into making second-tier investments, then the audit proved to be, if anything, a detriment to the owners' sound financial decision making. When relying solely on a virtual audit, an owner is very likely to be led into making poor investment decisions. In this case, the audit provides the opposite of its intended function, to the point that the owner might have been better off with no audit at all.

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How Microgrid is Changing the Energy Landscape*

The Honorable William C. (Bill) Anderson

ABSTRACT

For the vast majority of people around the world, their electric power is delivered via a system that relies on centralized power generation coupled with significant transmission and distribution infrastructure to deliver electrical power from the site of generation to the point of use. That system has provided reliable and relatively inexpensive power to much of the world for well over a century. However, a new set of concerns and requirements point us towards an alternative approach to power generation and distribution. That alternative is microgrids. To many, microgrids appear as a new and novel idea. But, in reality the concept dates back to the origins of the electric industry. This old idea that is new again offers promise in terms of tackling some very real and very current energy issues, and promises to change the energy landscape of the future. Microgrid technologies offer real solutions to address the significant issues of (1) accessibility, (2) recovery, (3) resiliency, (4) economy and (5) sustainability.

INTRODUCTION

The early days of the electricity industry pitted two industrial titans against each other. The inventor, Thomas Edison battled the entrepreneur, George Westinghouse to set the ground rules by which the electricity industry has played for more than a century. Westinghouse's vision of a centralized system, made possible by the development of a power generator capable of producing alternating current won out over Edison's distributed generation model. Economies of scale had a big hand in tipping the scales in favor of the Westinghouse approach.

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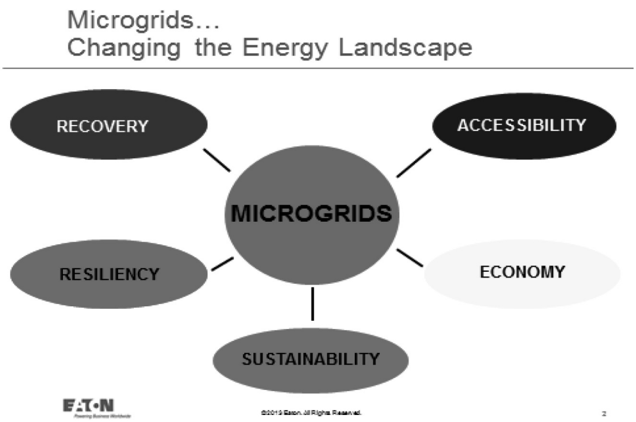
The centralized system has served the world well for more than 120 years, and will likely continue to be a cornerstone of power generation and distribution for many years to come. However, a very significant set of newly-emerging issues, as well as long standing weaknesses associated with the centralized model, suggests that a different approach must be adopted to deliver assured, reliable and affordable power to every corner of the globe. That different approach is microgrids…the concept developed by Edison…although he never used that term.

The array of issues that require significant and immediate attention span a significant gamut…from cost to national security. Microgrids offer one very powerful option to address identified weaknesses in the current electrical system effectively and economically. The most critical of these issues are outlined below.



ACCESSIBILITY

The stark reality is that our world is…and is expected to continue to be…energy poor. That is not to say that we lack the traditional and renewable feedstocks necessary to meet global demand. What is lacking is the infrastructure and investment dollars to deliver energy to the point of use in many parts of the world…predominantly emerging economies and remote locations.

Over 1 billion inhabitants of this planet have no access to electricity. In Sub-Saharan Africa, for example, 70% of the population is without electric power. Even in one of the most energy-rich regions on the planet…Alaska…access to reliable and cost-effective electricity is currently out of reach to many Alaskan Native villages in the State. Remoteness, lack of infrastructure, and the harsh environment have profound effects on energy needs, costs, and accessibility.

The areas of greatest concern are normally not within the reach of electrical transmission and distribution systems that could carry electricity from mega power plants long distances away. Great distances and sparse populations do not lend themselves to a financially sustainable solution set of centralized generation and long range transmission.

Certain rudimentary requirements for electrical power in emerging markets and remote villages are currently satisfied via diesel generator sets. Reliability, cost, coverage and the fuel supply chain continue to challenge the practicality of this solution set. The "plug and play" nature of hybrid microgrids allows for multiple electrical generation sources selected on the basis of locally-available energy feedstocks. This will allow for greater local autonomy over power generation assets and far less reliance on fuel supply lines well out of the control of the user.

The significance of microgrid technologies in changing the energy landscape for those 1 billion-plus people without access to electricity is not about options and economy. The significance is that hybrid microgrids currently provide the only viable solution to deliver adequate and reliable electrical power to a substantial percentage of the global population.

RECOVERY

Probably no event more poignantly illustrates both the criticality and fragility of our critical infrastructure more than a natural disaster. Electricity can be scarce, generators tough to acquire, and fuel supplies for those generators uncertain at best. Lack of power limits water pumping and purification, waste treatment, sterilization of medical implements, recharging of communication devices, and a host of other issues. Those with limited means to flee are forced to rely on shelters to sustain their lives.

A case in point is New Orleans in the days and weeks after Hurricane Katrina. Estimates vary widely, but suffice it to say that tens of thousands of New Orleans residents and visitors were forced to seek refuge in the Superdome…a facility designated by then New Orleans Mayor Ray Nagin as a shelter of last resort.

Katrina left most of southern Louisiana without power, including the central business district of New Orleans where the Superdome is located. The air conditioning in the arena failed immediately. Some lighting was maintained via an emergency generator, but that unit quickly failed. A back-up generator also soon faltered. The city's water supply held on a bit longer but finally gave out, so toilets in the Dome became inoperable and began to overflow. A facility that was pressed into service presumably as a safe haven for those without the means to flee the disaster soon spiraled into chaos and lawlessness, putting countless innocent survivors of the hurricane at peril.

This story repeated itself in the aftermath of Superstorm Sandy. In New York City, the loss of power and the absence or failure of backup generators, translated into (1) the shutdown of heating systems, life support, and other technologies that were vital to people's survival; (2) more than 1,000 patients having to be evacuated from New York metro area hospitals; and (3) the loss of power presented a distinct threat to people living in high-rise apartments. The elevators stopped working, and people physically unable to descend the stairways were trapped for days and even weeks.

To address these significant risks, emergency responders in the U.S. have historically, and continue to, rely on a patchwork of small emergency generators to provide critical emergency power. This solution is not capable of providing the significant amounts of power necessary to provide adequate relief in larger metropolitan areas. In addition, this approach relies on a supply chain of liquid fuels to run the generators… at a time when transportation routes…roads, rail and airports…have likely been severely compromised by the same catastrophic event. Until recently, emergency back-up generators were the only solution. Recent developments in microgrid technologies, however, provide an opportunity to change the playing field in terms of recovery of the electrical system in an impacted region.

The solution set contemplated here requires a shift in thinking from our current mindset of utilizing temporary standby power generation equipment dedicated to a single user to a solution providing critical power to multiple users from one source. At the heart of this approach would be advanced hybrid mobile power systems that can be deployed easily and rapidly to improve resilience. These systems would be specifically designed to be able to leverage existing energy assets that recovery workers find when they arrive in the impacted area, and can be augmented by additional generation equipment transported to the region as part of the recovery effort.

Over the past few years the Department of Defense has supported a number of microgrid demonstration projects. The lessons learned from those projects, when combined with efforts undertaken by the private sector, provide the building blocks to design and construct a new class of advanced hybrid mobile power generation and distribution systems to assist in providing the level of critical power truly necessary to support disaster response efforts. This could be accomplished through a unique and proven approach that delivers electrical power by tying into the surviving components of existing electrical grid in the impacted area. The utility grid operates at higher voltages (23, 13.8, 13.2 or 4 Kilovolts) necessary to manage and move the large quantities of power necessary to support larger islands of refuge as well as critical utilities like water/ wastewater needed to support relief locations. Generators used for back-up power (generally operating at 480 or 208 volts) cannot directly feed into existing utility power grids. Therefore, to appropriately leverage these generators in an integrated system, electrical power coordination is required. In addition to the ability to draw from multiple generation sources…both already on location and those brought in post-event… these systems will provide the key features of source management, distribution protection and load management.

Systems can now be designed to be completely self-contained, readily transportable, and in a plug and play configuration for quick commissioning by local electricians and utility workers These sophisticated systems can be designed to integrate mobile distributed generation control, renewable energy generation sources, energy storage, distribution bus protection and load. Functionality offered by these systems necessary to maximize the effectiveness of power delivery and control in the aftermath of a major event include:

1. Direct start-stop of generation assets to ensure efficient use of limited fuel sources.

2. Comprehensive load management to insure continued safe power distribution by shedding loads based on priority, resource availability and reserve capacity.

    a. Loads can be shed and recovered according to contingency type, disruption duration and online generation capacity.

3. Communication capability ensures the energy storage components have the capacity and state of health to provide power to the microgrid for transient mitigation, peak shaving of generation assets and stand-alone operation.

    a. Additionally the energy storage can be managed as a load during charging to ensure the demand is appropriate for maximum generator efficiency.

The approach as detailed above requires a device to seamlessly integrate various power generation assets and storage devices, connect to available surviving grid infrastructure and to effectively manage load requirements to safely provide power as needed to adequately support recovery efforts. One such solution is the Modular Integrated Transportable Substation ("MITS"), which can serve as a "universal adapter" to integrate into any grid (utility or commercial).

Modular Integrated Transportable Substation.
Photo courtesy of EATON

The MITS system will allow for a speedy connection to the grid and the restoration of power in a safe temporary manner. The mobility of this solution allows for flexibility in delivering electrical power to affected communities. MITS provides the flexibility to connect to the grid based on the available utility voltages in any affected area. The unit can be mounted on a trailer or a skid to allow for easy transport by road, rail or air. Designed for quick set up and connection, the unit can be operational within 4 to 8 hours of delivery to the site. Each unit can supply enough power to support the equivalent of 400 homes. And once the crisis is over, these units can be disconnected, removed and staged for use again for response at the next crisis.

RESILIENCY

The electrical grid in the United States is vulnerable to widespread and long-term service outage. These vulnerabilities come both from the complexity and age of the system, as well as from the rapidly increasing use of advanced electronics and computers to control the system. Threats to the grid can come from natural and manmade events, both of which have been experienced in the recent past across the country.

Alarm bells are being sounded by elected officials and senior Administration personnel. Former Secretary of Defense Leon Panetta warned that a "cyber-attack perpetrated by nation states or extremist group [would be] as destructive as the terrorist attack on 9/11." One would expect such a stern warning to result in swift and significant actions. However, Senator Susan Collins has lamented that "in all my years on the Homeland Security Committee, I cannot think of another issue where the vulnerability is greater and we've done less." In a May 21, 2013 report authored by the staffs of Congressmen Ed Markey and Henry Waxman it was acknowledged that "in light of the increasing threat of cyber-attack, numerous security experts have called on Congress to provide a federal entity with the necessary authority to ensure that the grid is protected from potential cyber-attacks and geomagnetic storms. Despite these calls for action, Congress has not provided any governmental entity with that necessary authority."

According to the U.S. Government Accountability Office (GAO), of the U.S. Department of Defense's (DOD's) 34 most critical global assets, 31 rely on commercially operated electricity grids for their primary source of electrical power. A 2008 Defense Science Board report noted that in most cases, neither the grid nor on-base backup power could provide sufficient reliability to ensure continuity of critical national priority functions and oversight of strategic missions in the face of a long-term (several months) outage.

Extended grid outages pose significant challenges to national and homeland security, as well as the ability of state and local agencies to provide basic services to citizens and critical local institutions. The needs and responses that will ensure energy surety at the federal, state and local levels are quite similar, which provides opportunities for various government agencies in the same area to partner in the development and execution of common solutions to the problem.

Solutions are available today that can deliver assured power to critical infrastructure during a prolonged grid outage. Advanced microgrids serve as the backbone of the solution. Distributed power generation assets, owned locally and operated locally, and fueled by locally-available energy feedstock can provide energy resiliency and surety throughout an extended outage. Incorporating local power generation assets utilizing microgrid technologies, these installations can be developed maximizing the use of currently installed electrical infrastructure, while taking advantage of private sector financing and government grants and credits to reduce the overall costs of infrastructure upgrades.

Recognition of the depth and breadth of the significant challenges associated with both recovery and resiliency of our critical electrical system infrastructure and functionality has greatly expanded over the past several years. A number of state governments…motivated in large part by lessons learned in the wake of Superstorm Sandy…and funded in part via federal dollars provided as part of the Sandy relief effort…have stepped forward to incentivize the development of secure microgrids in their respective states. To date, Connecticut, New Jersey, New York, Massachusetts and Maryland have established grant or loan guarantee programs intended to augment private dollars to accelerate microgrid project development, with a focus on securing the operation of pre-identified critical infrastructure necessary to provide protection and sustainment of the population before, during and after any catastrophic event.

ECONOMY

The economies of scale that weighed in favor of centralized systems during the Edison/Westinghouse era still largely maintain their advantage today. It is true that declines in the cost of modular technologies challenge the status quo, but a lot of ground needs to be gained for microgrid systems to come to complete cost parity with much larger fossil plants.

There are, however, notable exceptions to the general rule. Remote villages, for example, often present scenarios where microgrids can not only reach parity with current energy generation systems, but can offer significant cost savings. In many Alaskan Native villages, residents pay up to $0.60 per kilowatt-hour for electricity, resulting in bills for electricity and heating equal to one half of average monthly income. Hybrid microgrid solutions hold promise for significantly lower energy bills for residents of these remote villages.

In regions of the world where electrification has yet to occur, the substantial costs associated with power plant and transmission system construction present a scenario where microgrids often offer a significantly lower cost solution. Couple cost advantages with the logistical challenges of construction of an extensive power transmission infrastructure, and it is easy to see why the Power Africa initiative has acknowledged that distributed microgrids will be the centerpiece of the overall program.

Island nations and states face the same energy cost challenges as remote villages, so also present promise as early adopters of hybrid microgrid solutions. Even parts of the continental United States…mainly the Northeast and Pacific Coast…where utility rates are among the highest in the country, microgrid systems are beginning to become cost competitive…especially in states where funded microgrid incentive programs are already in place.

Finally, as demand charges become a larger percentage of the customer's overall monthly energy bill, microgrids move towards and beyond cost parity with grid-provided power.

SUSTAINABILITY

When we think of the definition of "sustainability," we quite naturally default to thinking in terms of environmental stewardship. And, of course, that is a critical component of sustainability. In the electrical world, environmental sustainability is achieved through the integration of renewable energy generation sources and via energy efficiency initiatives. As renewable or "green" power generation technologies mature and development of renewable energy projects proliferate, many will take the form of smaller projects installed close to the point of use. Microgrids offer an ideal platform to integrate these distributed renewable energy resources into the overall grid, while ensuring grid stability and power quality. In addition, the advanced control systems found in many microgrid installations can maximize the effectiveness of the power generation units, while at the same time manage the demand side of the equation, thereby driving the overall energy efficiency of the system.

But, the concept of sustainability encompasses much more than just environmental awareness. Financial sustainability, system reliability, resilience in the face of a catastrophic event and local autonomy all can be considered, weighed and prioritized when a microgrid system is designed. Because of the nature of microgrids…distributed power generation close to the point of use…the users set priorities, and have the opportunity to design a solution set that meets their particular sustainability goals.

SUMMARY AND CONCLUSION

The demands and challenges of the 21st century electricity marketplace are driving requirements to address a handful of critical issues that range from the basics of providing reliable and cost-effective electricity to large areas of the globe that have no such access today…all the way to protecting the most sophisticated and critical national security assets of the planet's most powerful nation-states. The task ahead becomes even more challenging as we are compelled to find new and more effective ways to prepare for and respond to major natural events that lead to widespread and prolonged power outages, while at the same time taking concrete steps to reduce the carbon footprint of humankind.

There are few "silver bullets" that we have at our disposal. But, in terms of meeting the most significant challenges facing the electric power industry in the 21st century, microgrids come as close to that silver bullet as could be imagined. An energy landscape that has seen very little in terms of change over the last century is witnessing the rebirth of an approach as old as the industry itself gaining new relevance in its inherent ability to address the most significant power challenges of our time.

ABOUT THE AUTHOR

The Honorable William C. (Bill) Anderson served as the Assistant Secretary of the United States Air Force for Installations, Environment and Logistics, as well as Air Force Senior Energy Executive, under President George W. Bush. He is a frequent author and requested speaker on topics including national security, energy, and leadership. He can be reached at co2rcr@hotmail.com.

EnMS and EMIS: What's the Difference?

Mike Brogan, Ph.D. and Paul F. Monaghan, Ph.D.

ABSTRACT

This article focuses on clearly identifying the two different ways that the expression "energy management system" is commonly used today. The conclusion is that future confusion may be eliminated by use of the terms: energy management system (EnMS); and energy management information system (EMIS).

INTRODUCTION

Often we ask people, "Do you have an energy management system?" What we mean by this is a full formal EnMS, like ISO 50001 or SEP (Superior Energy Performance). Often, the other person says they do, but what they really mean is that they have a monitoring or energy data analysis system or a building energy management system (BMS/BEMS/EMCS/BAS) for equipment control.

"Energy management" is a term that is being used quite broadly at the moment. Clearly, it can mean very different things to different people. In this article we explain what the difference is between the two terms, energy management system (EnMS) and energy management information system (EMIS).

We aim to explain how an EMIS is part of a complete EnMS. The key is how one integrates them!

At the end of this article is a list of definitions of commonly-used energy management terms. Each of these is categorized as "EnMS" or "EMIS."

EnMS & EMIS

An EnMS is a framework by which an organization establishes processes to achieve control and improvement of energy performance—a systematic approach to energy management.

Think of an EnMS as the umbrella under which those processes relate and interact. An EnMS is often viewed as having two aspects: "Management" and "Technical." The relationship diagram illustrated in Figure 1 supports this concept, using the terminology of ISO 50001.

The left side of the diagram illustrates the "Management" type processes involved in an EnMS, such as, gaining management commitment (e.g., top management providing necessary resources for the EnMS to be successful), the establishment of good systems for audits, corrective actions and management review. It also guides an organization towards nurturing and promoting an energy efficient culture by training, communicating and promoting good energy saving practices effectively with all staff from top management downwards.

On the right, the "Technical" processes involved are illustrated, such as, energy planning (e.g., establishing an action plan based on relevant objectives and targets, realized during an energy review; establishing an energy baseline, energy performance indicators (EnPIs)); monitoring, measurement and verifying action plan results. Within this analysis, an EMIS deals directly with monitoring and measurement.

The EMIS is a critical part of the EnMS. The EMIS collects data that supports many aspects of the EnMS (the energy review, the calculation of an energy baseline, EnPIs, and to verify the action plan results). However, the EMIS delivers no value unless the right data is collected and it is analyzed and used in the right way.

For example, we have often heard the following statements:

- "I never have time to look at the data"
- "We are swamped with data"
- "We have 100 meters for electrical consumption but only 1 meter for steam"
- "I can't remember how to generate new energy reports"
- "I do a lot of work producing great energy reports but no-one does anything with them."

These statements are clear signs of a non-systematic approach to energy management.

This is where the EnMS supports the EMIS investment. For example, the EnMS:

- ensures that the team has objectives set and time allocated for energy reporting;

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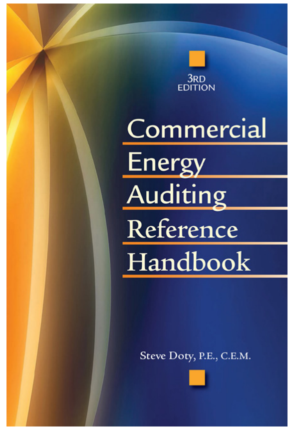
Steve Doty, PE, CEM



This book is designed to serve as a comprehensive resource for performing energy audits in commercial facilities. The fully revised new edition has been updated and expanded throughout, including new chapters on water efficiency, and impact of the human and behavioral aspects of energy management, as well as discussion of regression, use of energy consumption signatures as an operational control, and interval data information. Although there are no "typical" commercial buildings, the book begins with the premise that when commercial facilities are subdivided into categories based on business type, many useful patterns can be identified which become generally applicable to the performance of an effective energy audit. Hence, discussion of procedures and guidelines is provided for a wide range of business and building types, such as schools and colleges, restaurants, hospitals and medical facilities, grocery stores, laboratories, lodging, apartment buildings, office buildings, retail, public safety, data centers, religious facilities, laundries, warehouses, and more. All focal areas of the building energy audit and assessment are covered, including building envelope, lighting, HVAC, controls, heat recovery, thermal storage, electrical systems, and utilities.

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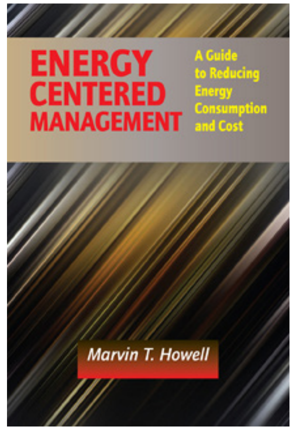
Marvin T. Howell



This practical, hands-on reference is designed to serve as a guide for any organization in planning, developing, and implementing an optimally effective energy cost reduction and management program. The information presented is intended, first, to facilitate the achievement of energy reduction deployment (ERD) which includes top management, all employees and onsite contractors. Although ERD, implemented by itself, can indeed render significant energy reductions, the book shows how to accomplish even greater savings by putting in place an energy centered management system (ECMS) which can identify and address additional critical sources of preventable energy waste. It also clarifies specific measures necessary to conform to the ISO 50001 energy management standard. The author has included a useful checklist, information on how to perform an internal audit or self-inspection, and tips on the best ways to create an overall energy awareness organizational culture.

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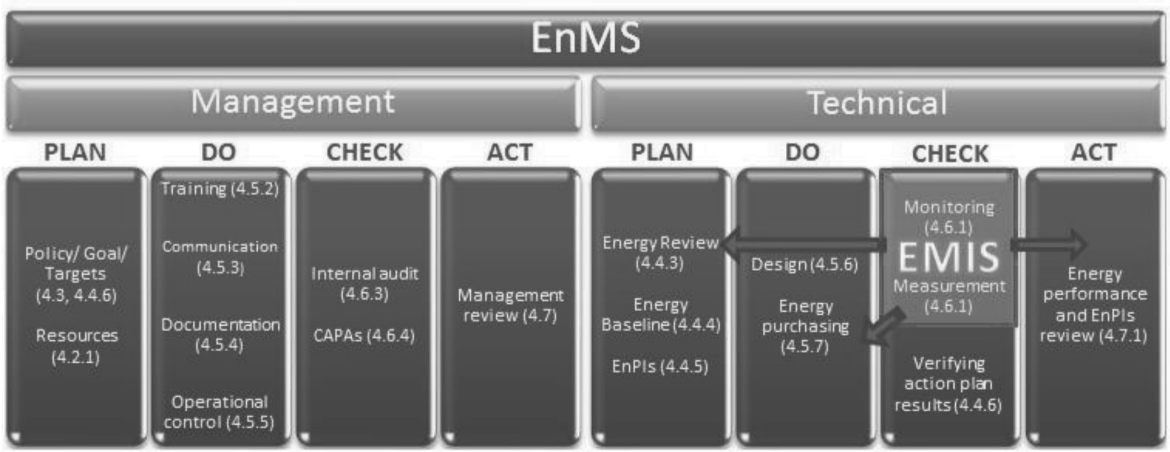

Figure 1. Energy Management System (EnMS) Diagram

- defines the key data to be analyzed and what the important EnPIs (energy performance indicators) are;
- based on SEUs (significant energy uses), defines the key locations where metering investment is really needed;
- ensures training is well managed;
- ensures continuous action is driven by key performance data, based on clear policy and energy management plans.

CONCLUSION

The bottom line: EMIS is an important part of the EnMS; EMIS data (properly used) supports good EnMS decision-making; the EnMS guides EMIS design and ensures good return on the EMIS investment.

EnMS and EMIS are both important. However, in communication, we should be clear when the energy management system we describe is "EnMS" or "EMIS."

TERMINOLOGY

BAS: Building Automation Systems (EMIS)
BMS/BEMS: Building (Energy) Management Systems (EMIS)
EIS: Energy Information System (EMIS)
EMCS: Energy Management and Control System (EMIS)
GSEP: Global version of SEP program (under development) (EnMS)
M&V: formal measurement and verification—M&V adds value by increasing the credibility of energy performance results. (EMIS)
ISO 50001: an International Standard describing a formal energy management system (EnMS)
ISO 50015: an International Standard that establishes guidelines for measurement and verification, M&V, of (a) energy performance and (b) energy performance improvement of an organization. (EMIS)
SEP (Superior Energy Performance): SEP certification is a US program that recognizes facilities that demonstrate excellent energy management practices and sustained energy savings. SEP incorporates ISO 50001 but also includes M&V and gives different levels of awards, based on amount of energy saved. (EnMS)

ABOUT THE AUTHORS

Mike Brogan, PhD, CEO of Enerit, has over 20 years of experience in the area of energy management. He has project-management enterprise-wide ISO 50001 and SEP software solutions deployments throughout Europe and North America. Mike is delegated to the ISO Technical Committee 242 (Energy Management), as an expert in developing guidance for implementing an ISO 50001 EnMS. Dr. Brogan may be contacted at mike.brogam@enerit.com or on LinkedIn at www.linkedin.com/in/miketbrogan.

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Teaching Pneumatics Controls with New Tricks: Case Study on Existing Buildings Getting Intelligent Solutions*

Consolato Gattuso, *Leo O'Loughlinm*, and *Harry Sim*

ABSTRACT

Intelligent buildings promise the ability to significantly improve energy efficiency and reduce operational costs by constantly monitoring and optimizing millions of data points from equipment and sensors. However, only newer buildings with modern automation systems can take full advantage of this. Older buildings that employ pneumatic and analog control technologies, typically constructed before 1999, must undergo very costly and disruptive upgrades to enable them to be smart.

In recent years, innovative non-invasive technologies were introduced that significantly reduce the cost to retrofit an existing building compared to conventional direct digital controls (DDC) upgrade. This article describes the project at 311 South Wacker Drive, a 65 story hi-rise acquired by Zeller Realty in early 2014. This 1.4 million sq-ft Class A office tower in Chicago was upgraded to an intelligent building at 70% lower cost than using DDC, achieving a 1.7-year payback.

INTRODUCTION

"Intelligent buildings," "internet of things," "cloud solutions"…. these concepts generate a lot of discussion in the buildings community. For facility operators, they promise the ability to remotely monitor and manage buildings to improve energy efficiency and reduce operational costs. This technology can gather millions of data points from individual pieces of equipment across a building portfolio and analyze them in real-time using complex algorithms. When the system identifies an anomaly, it can often diagnose the cause and make adjustments to correct the problem (Figure 1). Cost savings are realized via reduced energy

*Originally published at the West Coast Energy Management Congress 2015

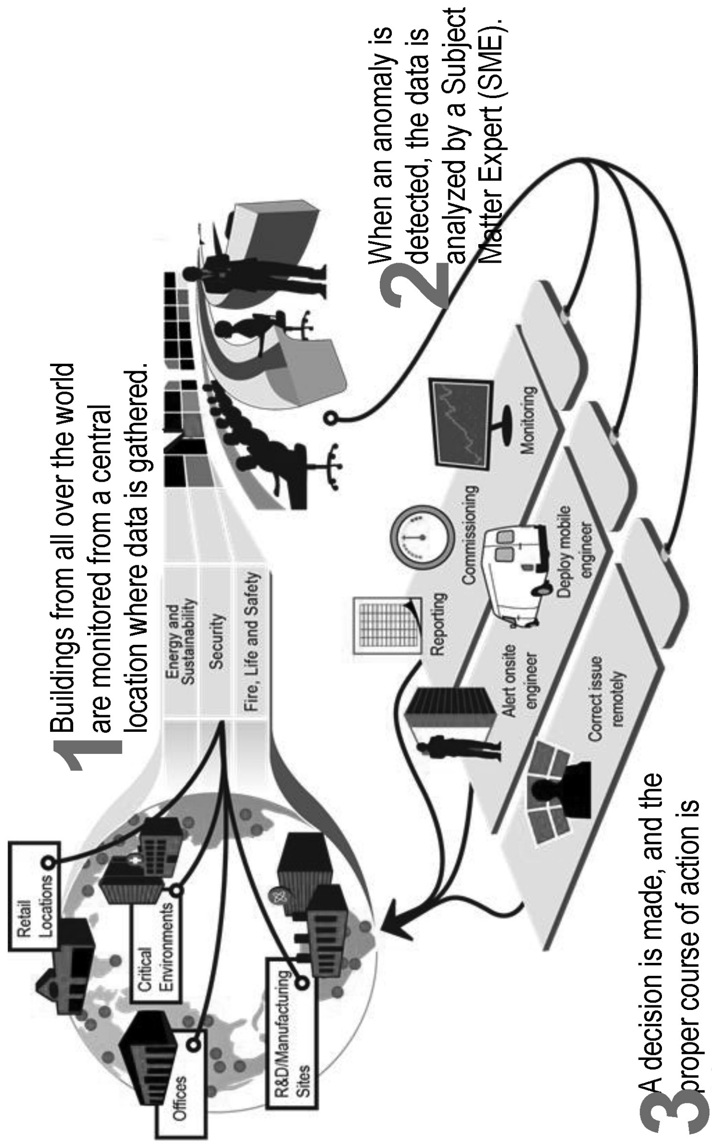

Figure 1. Intelligent Building Platform

costs, lower maintenance costs, and longer operational life for equipment. An intelligent building would typically cost 10% less to operate than a conventional building.

CHALLENGES FOR EXISTING BUILDINGS

However, only newer buildings already equipped with networked sensors and automation systems can take full advantage of intelligent building software and algorithms. Older buildings (constructed before 1995 generally) are frequently considered to not be good candidates because they employ pneumatic and analog technologies that provide little or no data visibility. More than half of all existing non-residential buildings fall in this latter category, including some of the most prestigious buildings in the country.

The 65-story tower at 311 S. Wacker Drive in Chicago is one such example (Figure 2). It is located by the Chicago River and boasts an impressive two-level, 50-foot-tall glass-ceilinged “winter garden” with palm trees and a fountain. Built in 1990, its building automation system was upgraded in 2000. Yet, virtually all of the tenant space still relies on pneumatic thermostats with no remote monitoring or control. If a space is too hot or too cold, a tenant must alert the facilities staff. The building cannot implement energy savings strategies such as night and weekend setbacks, optimal start/stop, auto-demand response, duct static pressure control etc.

NON-INVASIVE LOWER COST SOLUTION

Immediately after acquiring the building, Zeller considered upgrading to a direct digital control (DDC) system, but found that would incur unacceptable cost and also significant disruption to tenants, involving cutting open ceilings and walls. After evaluating different technologies, Zeller decided to implement a novel non-invasive retrofit technology called the wireless pneumatic thermostat (WPT). The WPT can be implemented in a fraction of the time and cost of conventional DDC, but provides essentially the same functionality (Figure 3).

950 WPTs were installed in approximately 6 weeks (compared with many months required for DDC) and were fully integrated with the JLL

Figure 2. 311 South Wacker Building

IntelliCommand cloud-based intelligent building platform to provide remote visibility and control to 1.5 million sq ft of tenant space—for the first time since the building was constructed.

The combined WPT and intelligent building software was then programmed to implement advanced energy savings and optimization strategies including occupancy-based setpoint control, "deadband" setpoint control, fan duct static pressure control, optimal start/stop, supply temperature resets, and monitoring based commissioning (Figure 4). The system also provides advanced dashboards and analytics to improve the effectiveness of the building staff (Figure 5).

In the first six months after the retrofit was completed, the building has already seen a reduction in HVAC energy use by 25%. Based on the savings the project qualified for rebates from Commonwealth Edison for 50% of the total cost, resulting in a payback period of 1.7 years. The $400,000 rebate was the largest ever energy savings award given to a commercial building by Commonwealth Edison.

The 311 South Wacker project is an excellent example of how cost-effective intelligent building technologies can unlock the energy savings potential inherent in the huge existing building stock.

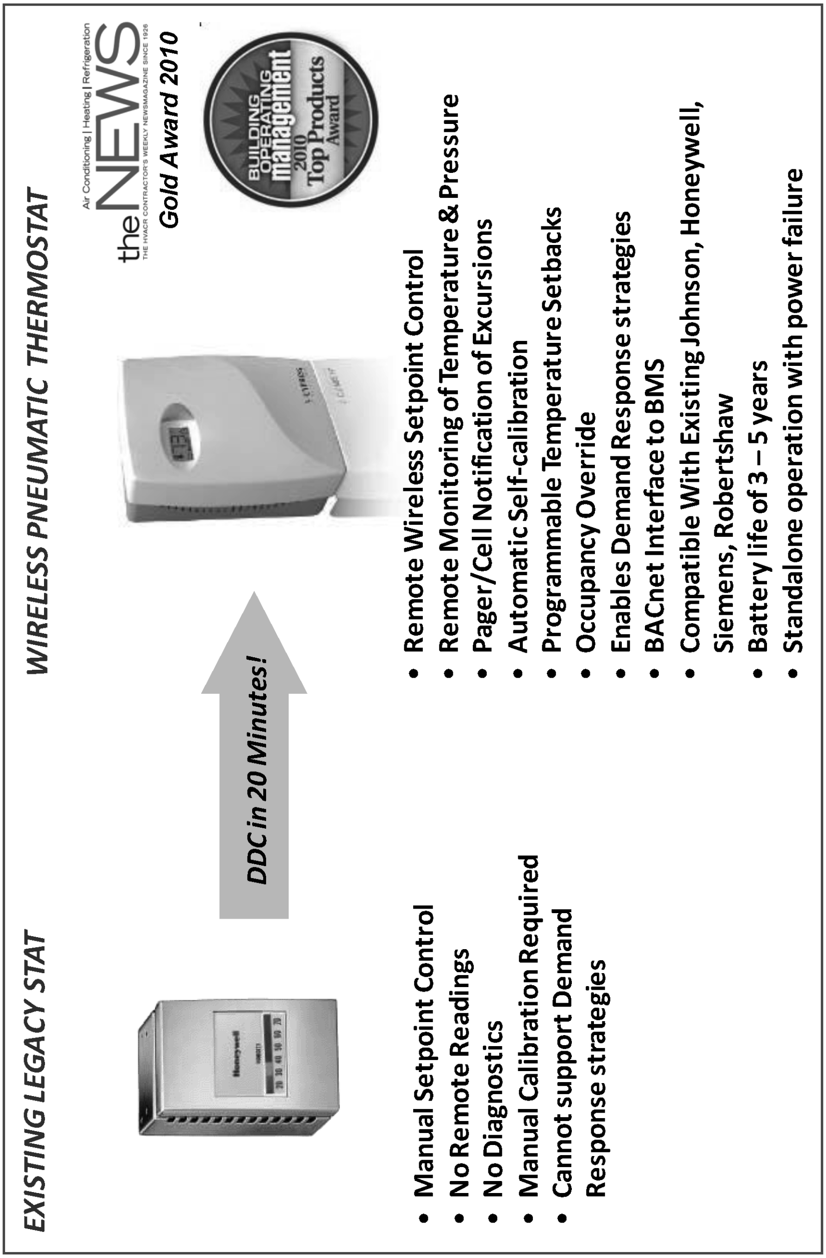

Figure 3. Wireless Pneumatic Thermostat Non-Invasive Retrofit

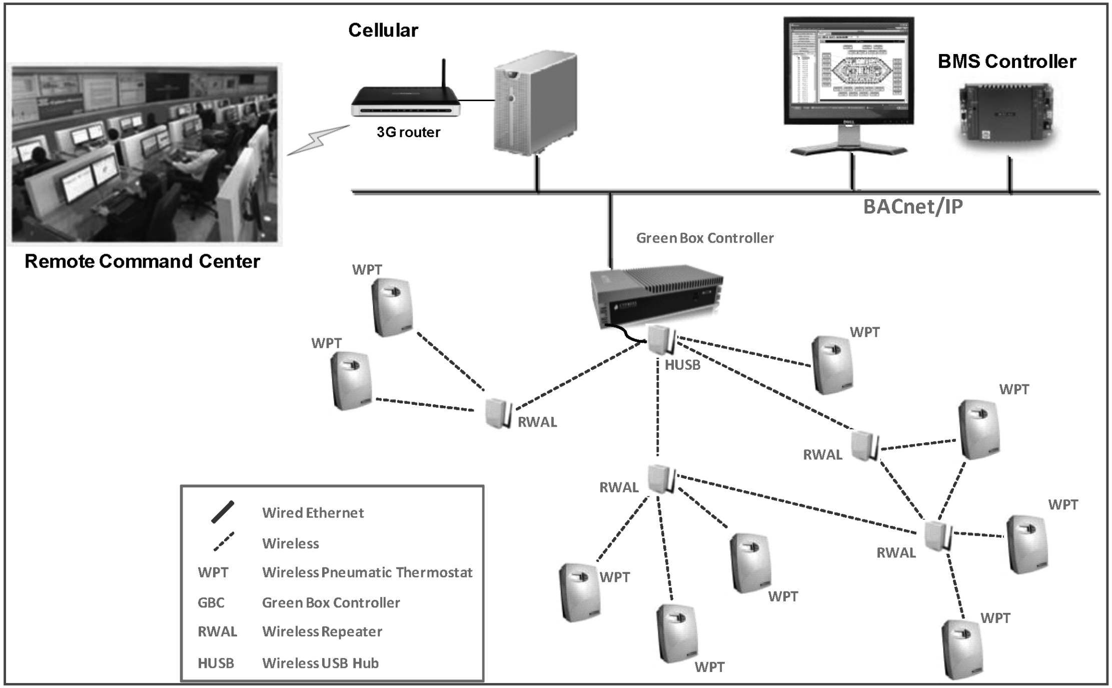

Figure 4. Intelligent Building Platform with Wireless Pneumatic Thermostats

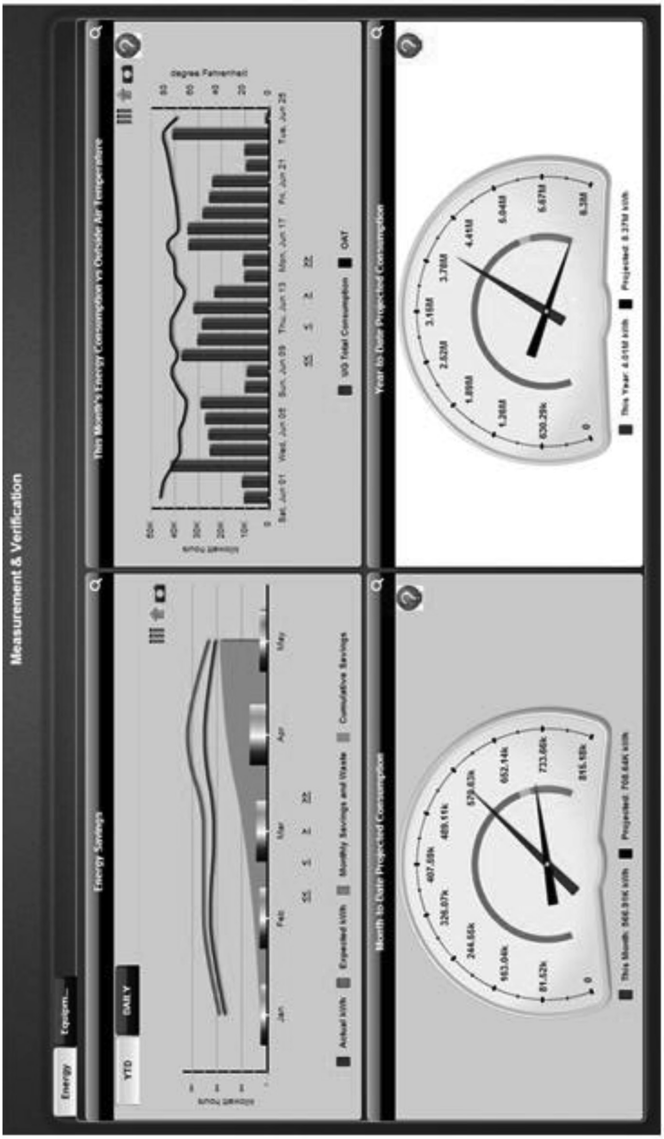

Figure 5. Remote Dashboards for Full Building / Portfolio Visibility

CONCLUSION

Even existing buildings with legacy pneumatic and manual technologies can be retrofitted to become an "intelligent building" at a reasonable cost with payback periods as short as 1.7 years.

Further Background and References

Zeller Realty Group, 311 South Wacker Dr.; http://www.zellerrealty.com/311-south-wacker

US General Services Administration—Wireless Pneumatic Thermostat Findings; http://www.gsa.gov/portal/content/215315

Smart Buildings Institute—Smart Building Overview; http://www.smartbuildingsinstitute.org/

Jones Lang LaSalle—IntelliCommand Smart Buildings Platform; http://www.us.jll.com/united-states/en-us/intellicommand/

Cypress Envirosystems—Wireless Pneumatic Thermostat—http://www.cypressenvirosystems.com/products/wireless-pneumatic-thermostat/

ABOUT THE AUTHORS

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Harry Sim is the CEO of Cypress Envirosystems, a company that focuses on improving energy efficiency in existing facilities. Harry believes in the need for non-invasive and fast payback solutions to retrofit existing buildings. He has been involved in all phases of developing products and applications for energy efficiency for existing buildings and industrial plants. Prior to Cypress Envirosystems, Harry was a Vice-President at Honeywell Automation and Control Solutions, working in the Building Automation, Industrial Automation, and Wireless and Sensors businesses. Prior to Honeywell, Harry was a Payload Director at NASA's Mission Control Center in Houston for Space Shuttle mission STS-40. He has lived and worked in the US, Canada, Europe and

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Secret Benefit #3
Special Tax Benefits for 2016

Eric A. Woodroof, Ph.D., CEM, CRM

ABSTRACT

If your 401k could yield a 35% return every year over 7 years, would that be attractive? Of course it would! What if you could find an investment in your own commercial building that would yield a minimum 35% return, and quite likely over 50% guaranteed? It may sound "too good to be true," but this has already been done.

INTRODUCTION OF BENEFIT

Most simple energy efficiency upgrades yield a 35% return, and there is much less risk than trusting your money with "Wall Street" investors. The "catch" (to take advantage of the special tax deductions and achieve 35% to more than 50% returns) is that you must implement projects in 2016… which means you should start now.

CALCULATIONS

Don't worry, these are simple projects (like lighting retrofits) that you can do yourself. Even for small offices, this can be a "winner." For example, Table 1 illustrates a real case study from Kentucky (where energy rates are very low compared to the US average).

Table 1. Case study economics for a small 2,000 ft^2 office

Project Total Cost	$2,116
Utility Rebate	$ 188
Tax Benefit (Retrofit is an Expense)	$ 698
The "After-tax" Cost	$1,230
$729/year savings for next 7 years	$5,103
Annual Return on Investment	**59%**

Plus, there is a *special tax deduction* of $1.80 per ft^2, which would be an additional $900 (minimum tax deduction) for the building owner.

Of course, the larger the building, the greater the savings. In addition, you can finance projects so you could spend zero dollars upfront.

FOR MORE INFORMATION

If you would like to learn more, this link leads to a free 3.5-minute video that explains the special tax deductions available for 2016: http://www.profitablegreensolutions.com/content/2016-special-tax-credits.

This additional free video shows the economics in a "high bay" LED retrofit, which is useful for industrial warehouses and even gymnasiums: http://www.profitablegreensolutions.com/content/ballast-free-led-retrofits.

Hope this helps you.

ABOUT THE AUTHOR

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