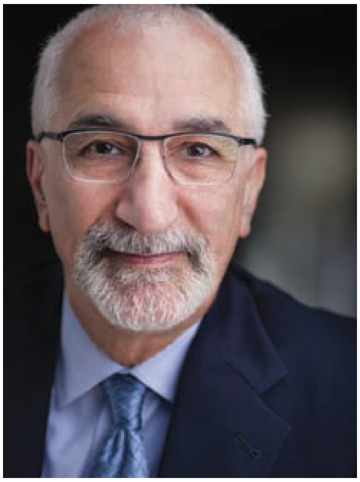
Energy Efficiency – The Art of Measurement

Modernizing Measurement & Verification (M&V)



By Hossein Haeri

Investment in energy efficiency has grown by leaps. With fresh ideas, methods for measuring the effects are catching up.

For the past forty years, ever since regulators and policy makers woke up to the promise of managing demand as a substitute for building power plants, efficiency has established itself as the least expensive and cleanest energy source. For several states, it is the fuel of first choice.

Investment in publicly funded energy efficiency rose to nearly eight billion dollars in 2017, with every major utility in just about every state offering efficiency programs.

Such massive growth would have been improbable without the work of evaluation, measurement and verification experts (EM&V's), who helped make the case for energy efficiency by building trust in its results. Though this claim may sound outrageous, it is not.

EM&V underpins much of the consumer-funded energy efficiency enterprise. The experts help program administrators track their programs' performance, and they bolster the public's and regulators' confidence that ratepayer funds are spent prudently.

EM&V encompasses a wide range of research activities in energy efficiency, aimed at answering important questions about the performance of publicly funded programs such as process efficiency, consumer satisfaction, and cost-effectiveness.

These topics deserve careful consideration, but, at its core, EM&V is a means for measuring and managing uncertainty.

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Measurement and verification (M&V) is EM&V's centerpiece. Its focus is on measuring the realization of expected savings, a metric that matters to everyone participating in the energy efficiency market. The results enter into planning, regulatory, and contractual decisions such as resource adequacy, regulatory compliance and prudence, and contract fulfillment.

Thanks to contributions from many academic and professional experts, M&V has become a well-established field of analysis, grounded in sound engineering, economic, and behavioral principles.

State of the Art

Generally, savings are determined in three ways. The first relies on deemed savings values, currently the most common methods for consumer-funded programs. It is the basis for calculating and reporting savings in thirty-six states.

Many states establish fully or partially deemed values through a formal, usually collaborative process. They record the results in technical reference manuals (TRMs), often sanctioned by state regulators.

This method works well for isolated measures. Accompanied by a rigorous process to verify the measures' proper installation and operation, it can yield reasonably accurate estimates for simple measures installed in large numbers.

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TRMs standardize saving calculations, improve the predictability of savings, and lower uncertainty for program administrators. A TRM is a choice that probably every state should adopt, if savings values are derived from current and accurate data, vetted by experts, and approved by regulators.

The second method, project-specific measurement and verification, has become the method of choice for programs that involve multiple unique measures and processes in larger and more complex facilities or new construction projects.

This approach follows the guidelines set by the International Performance Measurement and Verification Protocols. Implementing it generally demands specialized calculations, energy simulation modeling, metering, or statistical analysis of energy consumption trends.

The third method uses large-scale statistical analysis of consumption data to estimate savings by comparing energy use before and after a measure is installed. This is the oldest and most common way to measure savings from residential programs and remains M&V's gold standard.

This inexpensive option, properly applied to sufficiently large samples of participants, provides reliable estimates of savings for programs that target homogeneous populations.

None of these methods perfectly substitutes for direct

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measurement, but, in capable hands, they can produce reasonably reliable savings estimates well within acceptable margins of error. The trouble is that there has been a lack of commonly accepted procedures for applying these methods. There are inconsistencies not only in the choice of method, but also in how it is applied and how the results are interpreted and reported.

To meet increasingly aggressive performance targets, energy efficiency program administrators have begun to offer a wider range of new products and measures to a broader population of consumers. And they are using creative delivery mechanisms that involve engaging market participants at different points in the supply chain.

These developments, coupled with advances in communication and telemetry that allow program administrators to interact directly with consumers through intelligent devices, are fundamentally transforming the energy efficiency markets in many parts of the country.

At the same time, regulators and critically, utility planners, are demanding greater certainty in program results and reliability as savings accumulate and claim increasingly larger shares of many utilities' resource portfolios.

M&V experts are taking steps to meet these new demands. Three trends are helping to shape this drive. First, the industry works to standardize its methods and bring greater consistency in calculating, verifying, and reporting savings.

Second, developments are underway that aim to lower M&V costs through automation. Third, there is a growing interest in confirming saving at broader, system-wide or regional and national levels.

Drive for Uniformity

In 1996, the North American Energy M&V Protocol, one of the most comprehensive and collaborative attempts to create standardized methods for measuring savings, called for procedures "that, when implemented, allow buyers, sellers and financiers of energy efficiency projects to quantify and measure performance" and are "consistently applicable to similar projects [in] all geographic regions...and are nationally accepted, impartial and reliable."

Many attempts have since been made to achieve this goal, by a wide range of entities. That includes federal agencies, state regulators, utility associations, energy efficiency service providers' associations, professional associations, regional grid operators, ASHRAE, the American National Standards Institute, and the International Organization for Standardization. Not to mention various initiatives in Canada and Europe.

Every one of these attempts has made notable incremental contributions to advancing M&V, but none succeeded in drawing widespread acceptance.

A series of initiatives are now underway that can change this. The first is the Uniform Methods Project (UMP), sponsored by the U.S. Department of Energy, that seeks to document commonly accepted measure-specific M&V methods and practices.

So far, the project has produced M&V protocols for twenty-one common measures. Given the large number of measures filling today's program portfolios, this compendium may not appear as encompassing as one might expect. However, the scope and significance of the project becomes apparent when we recognize that the protocols account for more than three-quarters of the savings reported by most program administrators.

What makes the UMP unique is that it is a collaborative undertaking, led by stakeholders. A steering committee made up of representatives from public utility commissions, state energy offices, utilities, and non-governmental organizations sets the guidelines, decides which measures should be covered, and approves the assignment of experts to draft each protocol.

A M&V practitioner who is an expert on the subject consults with a group of practitioners, and they develop each measurement protocol. The protocol undergoes a formal public comment process before publication.

Rather than offering specific values, the protocols are meant to guide calculations, and are intended to be expository rather than specific and prescriptive. The protocols leave some matters, such as appropriate statistical confidence or ideal precision in savings calculations, for the local policy makers.

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Measurement is commonly understood in terms of direct observation. In energy efficiency, however, savings or absence of consumption are determined not by evidence, but by inference. That is why energy efficiency has been called "the invisible fuel." This basic concept sits at the core of the art and science of measuring savings.

M&V finesses this problem by measuring savings indirectly, comparing observed energy use to what would have occurred in the absence of saving. This means inferring savings by confirming a so-called counterfactual.

However, there are no widely-accepted standards for which baseline-setting method should be applied to different measures and programs. This has left too much room for interpretation and created controversy. Two initiatives in California and Massachusetts – both pioneers in publicly funded energy efficiency and its largest per capita investors – are designed to change this.

The first effort marks an important development in energy efficiency policy. It took place in 2015 when the California Legislature passed Assembly Bill 802. The bill's most important aspect establishes a new statewide energy use benchmarking and public disclosure program for large commercial and multifamily buildings.

It also requires the California Public Utility Commission to update the rules for measuring energy efficiency and, where appropriate, use normalized metered energy consumption as the basis for measurement. The bill is important not only because it provides much needed direction for savings calculation, but because it advances energy efficiency policy in general.

The second initiative, the Commercial/Industrial Baseline Framework, sponsored by the Massachusetts Program Administrators and Energy Efficiency Advisory Council, is the most comprehensive and detailed account of the underlying principles and methods of setting baselines, to date. The Framework provides examples of energy efficiency measures and uses logic flow charts to guide the reader through the process for choosing a baseline. This is expected to be followed with a separate framework for residential measures.

Attempts to harmonize reporting M&V results is a natural extension of the drive to standardize methods. Several initiatives, notably those from the CPUC in California and the M&V Forum of the Northeast Energy Efficiency Partnership, provide excellent starting points for achieving this goal.

Standardization has its critics, who complain that it is burdensome, restrictive and expensive, especially for smaller program administrators. Though achieving consensus on universally accepted methods remains challenging, the benefits are enormous.

Skeptics are wrong in viewing these developments with wariness. More rigorous, standardized methods can only be useful. More uniform methods for measuring and reporting savings will not constrain energy efficiency, but will enhance it.

The Changing Perspective

Today's M&V methods belong to a mode of analysis that has come to be known as "bottom-up." As the name suggests, the bottom-up method involves estimating savings for individual measures of projects or facilities, and aggregating the results to determine a program's savings. This industry standard is widely used to verify savings for most programs in most states.

The method, however, has several shortcomings. First, it lacks a coherent and unified methodology, borrowing techniques from multiple disciplines to address specific M&V issues.

Importantly, it overlooks the fact that energy end use systems do not behave independently. Lower electricity consumption by one end use such as lighting could mean heating systems must work harder to compensate for the loss of waste heat that lights generate.

A related problem arises when two or more measures compete for the same end uses or complement each other. An energy-efficient heating system saves less energy if installed in a well-weatherized building than in a leaky one.

These dynamics, collectively known as "interactive effects," can distort savings for individual measures, especially when savings values are deemed.

Implementing these methods can also be expensive and time-consuming, which is why they are generally applied to samples of projects or facilities. If the results are then extrapolated to the program, this introduces additional bias.

The methods also cannot directly account for other, potentially confounding factors such as rebound, self-selection, measure retention, persistence, or indirect market effects. These effects must be accounted for using additional, complementary analyses, which add to M&V costs.

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These limitations have prompted evaluation experts to consider alternative top-down approaches that use aggregate consumption and macroeconomic variables to measure energy efficiency impacts at system or regional levels.

As in econometric forecasting, common among utilities, top-down methods use regression to explain aggregate energy use in terms of its determinants. With the exception that in top-down analysis, the demand equation includes a measure of energy efficiency program activity, usually expressed in terms of expenditures or expected savings.

There is also the matter of emphasis: whereas in forecasting, the goal is to accurately predict total consumption, what matters most in top-down analysis is the magnitude and accuracy of the estimated coefficient(s) for variables representing energy efficiency activity.

So far, the lack of high-quality data has been the biggest challenge to top-down analysis. Historical records of program activity tend to be short. With few exceptions, aggregate savings have been too small to be separated from statistical noise.

Fewer than a dozen studies have used the top-down method, producing mixed results, although the most recent experiments with the method in California and Massachusetts have been encouraging. While it is too early to tell what roles top-down methods can ultimately play in M&V, they present a valuable confirmatory exercise, providing the most convincing evidence yet of energy efficiency's real system-wide impact.

Automation and Innovation

Suppose you could bypass the whole M&V process by predicting savings using a single measurement of a home's or a facility's energy use – say, from a smart meter or a single sensor? Add automation to this mix, and a system takes shape with the potential to measure savings accurately, immediately as they occur, and at a low cost.

This is the premise and promise of automated M&V or MV2.0, a coinage attributed to Tom Eckman of the Northwest Power and Conservation Council, and Mark Sylvia of the Massachusetts Department of Energy Resources.

Automated M&V works in two ways. First, it uses existing consumption history to build a model that correlates energy consumption to certain determinants, such as weather. The determinants' actual values after a program is implemented are then inserted in the model to "predict" energy use in the program's absence. The difference between this predicted value and the observed consumption presumably reflects the program's effect.

The approach has its drawbacks. For one thing, its application is limited mainly to estimating aggregate-level savings of a house or facility where existing conditions represent the baseline.

It is less useful for evaluating savings in larger commercial facilities with more diverse and complex energy systems, or where codes or standards, not existing conditions, represent the baseline. Further, it does not work for programs designed to influence various stages of the supply chain rather than end users.

The second way, known as non-intrusive load metering (NILM), applies machine learning, a branch of artificial intelligence that allows computers to pick up patterns they were not explicitly programmed to perceive.

This involves taking measurements of a home's or a facility's total load and identifying different appliances by detecting their "signatures" and estimating their energy use by tracking when they turn on or off.

By applying the technique before and after an energy efficiency event, energy savings could be measured more precisely by comparing energy use of appliances and equipment before and after the intervention.

The results from recent tests of NILM tools are encouraging. Research by the Electric Power Research Institute estimated the accuracy of NILM predictions to be as high as seventy percent for major equipment (such as heating, air conditioning).

A similar study by the Pacific Northwest National Laboratory found similar results for electrical equipment that operate in a single (on or off) state. Predictive performance dropped to about thirty percent for appliances such as refrigerators, freezers, and pool pumps, that operate in multiple states.

Measuring savings for plugin measures presents another challenge because isolating these loads can be devilishly difficult: there are many of them, they use little power, and, unlike ordinary appliances, they operate at a variety of power levels.

These techniques have found a dedicated following, especially among technology vendors. A recent report from the Northeast Energy Efficiency Partnerships billed the idea as a change in the EM&V paradigm.

A similar paper from the American Council for an Energy-Efficient Economy contemplates a future where advances in information and communication technologies allow the possibility to "measure energy savings with the same accuracy and fluidity that utilities achieve in measuring electricity consumption" and allow savings to be traded "as a commodity… in regional capacity markets."

Another paper, from researchers at Stanford University, goes even further, praising energy load disaggregation as the "holy grail" of energy efficiency.

It is tempting to read these developments as the end of doing M&V in one way and the beginning of doing it in another: automation complements M&V and can help advance it. The recent developments deserve a cautious welcome in that anything that helps demonstrate energy efficiency's benefit can only be positive. The caution is because good ideas can be discredited if they promise more than they can deliver.

Designed and executed poorly, M&V can undermine a good policy. How we regard M&V depends on what we believe energy efficiency is for.

Technologies that support automated M&V have taken an increasingly important role in providing utilities with a platform to interact with their customers. By continuously providing an itemized account of their energy use through web portals, they make utility customers aware of exactly where their energy dollars go. This may be the valuable service these technologies are destined for.

Looking Ahead

Energy efficiency policy will continue to be judged by how savings are measured. Publicly funded programs are more likely to succeed if their results can be more accurately measured. Jurisdictions new to energy efficiency are more likely to move in the right direction if they can see tangible results elsewhere.

Lord Kelvin, the 19th-century English physicist who discovered the second law of thermodynamics, put it this way: "'When you can measure what you are speaking about and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind.'"

Much as it has sustained energy efficiency, M&V can also frustrate it. When designed well, drawing upon sound theory, well-executed, with its results clearly presented, M&V opens a space for evidence-based policy making.

Designed and executed poorly, M&V can undermine a good policy. How we regard M&V depends on what we believe energy efficiency is for. Energy efficiency's policy objectives have evolved, shifting from conservation and saving money on bills to integrated resource planning and now, mitigating environmental externalities.

The stakes in energy efficiency policy continue to rise beyond the local objectives of serving the interests of utilities and their customers, moving toward more global concerns over climate change.

So far, M&V has made impressive headway in meeting energy efficiency demands. Now, it must find ways to help energy efficiency meet its new challenges. Standardization, automation, more harmonized reporting, and new ways of evaluating the results offer a positive start towards achieving these goals. PUF

Excerpt From the Off-Peak Column in March's PUF

Remember The Jetsons? If you're old enough, the original series?

Almost nobody recalls that the original series was just twenty-four half hour shows during a single TV season, September 23, 1962 – March 3, 1963. Since The Jetsons had such an impact, and since it came at such a key time in our culture's history, most feel it lasted many more seasons.

Remember the simple theme song that opened the animation directed by William Hanna and Joseph Barbara?

Meet George Jetson, His boy Elroy, Daughter Judy, Jane his wife.

The Jetsons are flying through Orbit City in the future, the twenty-first century. Elroy and Judy are jettisoned to school, Jane to the futuristic mall.

Then George continues to his job at Spacely Space Sprockets. The family flying machine folds into a suitcase. Then George rides a moving walkway to boss Cosmo Spacely (voice by Mel Blanc).

The enormous appeal of the series was in large part that it predicted the future. Or more precisely, The Jetsons predicted the future of consumer technologies.

It's incredible. Here it is, the year 2017. And we're able to say that these predictions of the original series, made fifty-five years ago, were remarkably accurate.

Though these technologies didn't exist during the presidency of John Kennedy, The Jetsons rode moving walkways as we do in airports. Their dog Astro exercised on a treadmill as we do in health clubs and at home.

The series featured flat screen and large projection televisions, desktop and laptop computers, smart phones and watches. None of these existed in the early sixties when we changed the channel of our vacuum tube sets to ABC after dinner, at 7:30.

There's more. George reads his news on the Internet, and teleconferences with video. In a time when the morning paper and the evening news broadcast were the sources for the news. And when desk phones with dials were how we stayed in touch. Before area codes, and before country codes.

The Jetsons also predicted video cameras, and light sensors. How could Hanna and Barbara have dreamed up all these technologies that are so common today?

In their home at Skypad Apartments, The Jetsons have electric toothbrushes and a microwave oven. They also order goods at home. Amazon isn't yet, in 2017, delivering products with the speed of pneumatic tubes.

There's Rosey the Robot, back there in the fall of 1962. We're now using robots more and more.

Buildings in the early sixties generally had small windows. Not in The Jetsons. The buildings heavily incorporated glass, as does our present architecture.

The doctor's office in Orbit City has magnetic resonance imaging. Though MRI was invented fifteen years later, in 1977.

What if we revived The Jetsons? What predictions would it make for consumer technologies in, say, the year 2072, fifty-five years from now?

Hanna and Barbara succeeded so extraordinarily because they imagined how technology companies might focus, based on the fundamental wants and needs of consumers. If we did that, we might think up fabulous devices for our comfort, safety and entertainment. We might extend out the rudimentary steps to date in artificial intelligence, virtual and mixed reality, mind share, wearables, drones, 3D printing, etc.

And all these fabulous devices in 2072 will be electrical. As in 2017. As in 1962.