New Paradigms in Determining Gross Energy Efficiency Savings[1]

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ABSTRACT

Air quality, climate change, economic growth, and the pressure to keep customers' bills low, point the United States toward greater investment in energy efficiency (EE), but traditional EE measurement methods are limiting EE's ability to expand. The authors identify emerging savings measurement approaches that are more accurate, timelier, and less costly. By improving the way we calculate gross energy savings, the United States can pursue EE's potential and expand its role in national energy policy.

The authors highlight important areas to develop new methods for measuring energy savings, including recent Department of Energy (DOE) projects that could lead to improved systems for determining savings. These data-driven, forward-looking initiatives include:

- The State Energy Efficiency Action Network Evaluation, Measurement, and Verification (EM&V) working group – bringing stakeholders together to solve complex issues;
- The Uniform Methods Project - determining a single protocol for calculating savings for a particular measure, while balancing accuracy, timeliness, and cost;
- The Building Performance Database - facilitating a statistical approach to energy savings which could facilitate large-scale private financing of energy efficiency.

DOE activities are augmented by other factors that will contribute to a paradigm shift for EM&V:

- The expanding availability of self-monitoring and diagnosing equipment and buildings, allowing for near real-time assessment of equipment performance and use; and
- The spread of high frequency usage data available in near real-time, opening up new forms of analysis.

Introduction[2]

[1] The authors are indebted to Joseph Hagerman (now of Booze, Allen and Hamilton), George Hernandez (Pacific Northwest National Laboratory), and Cody Taylor (DOE) who are the source of some of the new and fundamental ideas presented here. The ideas expressed here are those of the authors and do not reflect the policies or position of the Department of Energy.

[2] This article is written from the point of view of the apparently simplest EE measurement problem: gross savings at the site or program level. The additional issues raised by attributing those results to specific actions or program components raises many more issues not addressed here. Accordingly, in this article, EE savings calculation only refers to gross savings.

Several recent trends have led the Department of Energy (DOE or Department) to consider how to advance the current practice of evaluation, measurement, and verification (EM&V) for energy efficiency (EE) in the United States. The current industry, after thirty-five years of development has reached a level of roughly $10 to $13 billion in annual activity.[3] The cost effective technical potential seems to be orders of magnitude larger (Choi Granade et al., 2009). Given the expansion of our nation's energy efficiency efforts, determining the savings, and thus the benefits from this investment has taken on greater importance. In parts of the country, energy efficiency is being achieved at a scale that requires that it be taken into consideration in load forecasting and resource planning. Additionally, states increasingly want to know if their efficiency programs are performing as well as those in other states. In some cases, utilities have the ability to earn incentives for achieving high levels of energy efficiency. In addition, national legislation has at times included energy efficiency in ways would have required a uniform method for calculating energy savings to ensure equity amongst the compliance entities. Such legislation was considered in Loper (2009) and Schiller et al. (2011) among others.[4]

It is unlikely that current EM&V practice can be effectively scaled up to meet these varied demands. DOE can help address both pervasive technical issues and the introduction of new audiences. A recent study by Cadmus highlights technical issues; Jayaweera et al, (2011) reviewed savings algorithms in numerous technical reference manuals (TRM) and documented the variability in the calculations used to arrive at savings estimates. While there are legitimate reasons why savings differ for the same program run in two different places, the savings also differ in part because of subjective decisions made by the evaluator. These TRMs and the broader EM&V practice in the United States have been dominated by the concerns of two constituencies, public utility commissions and utilities. New audiences require us to rethink our traditional approaches to EM&V. For example, for the finance industry to significantly invest in energy efficiency it will need inputs to analyze the risk associated with those investments, information not provided by traditional energy efficiency savings determination. Bringing new capital into energy efficiency is crucial to its growth. This paper briefly reviews the concerns and perspectives that arise from some of these new viewpoints, highlights some of the activities the Department has undertaken to address them, and identifies possible additional areas of work.

Current EM&V Practice

The practice of measuring gross energy savings has matured over the years, and it generally provides satisfactory answers for its specific application. However, these practices are not without their problems. Traditionally, most EM&V was done at the request of public utility commissions so that utilities could demonstrate benefits and recover the costs of implementing

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[3] ACEEE 2011 Scorecard for energy efficiency, p. viii indicates $5.5 billion in expenditures for 2010, and Satchwell (2010) indicates that the Energy Service Market was about $4 Billion in 2008 with forecasts of growth as high as $7 billion for 2011. Also see CEE 2011 Annual Industry Report

[4] An aspect of implementing legislation could be a standards setting process; the practioners of EM&V could find a standard setting process within a legislative determined time frame a challenging exercise.

efficiency programs. This practice has been documented in various published EM&V protocols. While this documentation has been important, it has not proven sufficiently rigorous to prevent serious disagreements about achieved savings between parties. Loper (2009) described the problematic role of EM&V in California's regulatory processes. In short, certain utilities were eligible to receive incentives in addition to their cost recovery for meeting certain energy efficiency goals. When it came time to determine incentive eligibility, the California Public Utilities Commission and the utilities disagreed over what level of energy savings had indeed be achieved. This type of regulatory risk is a significant concern to many utilities.

To facilitate the deployment of energy efficiency programs, several areas of the country have developed databases of standardized savings values (often called "deemed" estimates) as part of, or in addition to technical reference manuals (TRMs). While the jurisdictions and stakeholders developing each TRM may be satisfied with the values provided by their TRM, comparison of these values across TRM's (Table 1) shows surprising variation.

Table 1. Gross savings ranges for common energy conservation measures in regional technical manuals

Energy Conservation Measure	Minimum	Maximum	Range
CFL -	27 kWh/year	49 kWh/year	1:1.8
Ref recycling	482 kWh/year	1,728 kWh/year	1:3.6
Furnace replacement (gas)	5.54 MMBtu	12.7 MMBtu	1:2.3
Low-flow showerhead	130 kWh/year	583 kWh/year	1:4.5
	0.57 MMBtu/year	2.6 MMBtu/year	1:4.6
Unitary Air Source Heat Pump	164 kWh/year	951 kWh/year	1:5.8
Storage Hot Water Heater	99 kWh/year	347 kWh/year	1:3.5
	24 therms	57 therms	1:2.4
Electronically Commutated Motor Furnace Fan (Res.) p 42			
Energy Star© Refrigerator	45 kWh/year	106 kWh	1:2.4
Commercial Clothes Washer (electric)	224 kWh/year	921 kWh/year	1:4.1
Electronically Commutated Motor Furnace Fan: Commercial Refrigeration	264 kWh/year	1,216 kWh/year	1:4.6
Motors	387 kWh/year	662 kWh/year	1:1.7
Commercial Furnace (gas)	1.1 MMBtu/year	30 MMBtu/year	1:27.3
Commercial Storage Hot Water Heater	1.5 MMBtu/year	7.6 MMBtu/year	1:5.1

Source: Jayaweera (2011b)

To account for this variation, Jayaweera et al. (2011) summarize the inputs, equations and methods used for each calculation. They find that not all variation in the savings range can be accounted for by differences in inputs, and in many cases even the engineering algorithms differ.

Most troubling is their conclusion that it is not possible from documentation accompanying each TRM to account for these differences by observable or explainable phenomenon (weather, specific application of the measure, etc.). While each jurisdiction can be satisfied that the values listed in its TRM represents gross energy savings in its area, the lack of comparability from one TRM to another hurts energy efficiency's credibility.

Such variations have been identified at the local, national, and international level as well. Hence, DOE is monitoring and participating in the several new uses of energy savings calculations. These take the form of the use of energy savings metrics in new self-implementing (i.e. at the enterprise scale) programs, and the connection to international developments such at the new international standard for energy management (ISO 50001).

Limitations of Current Practice

Current gross savings calculation approaches would be unlikely to be able to support significant increases in EE activity in their current form. Financial industry investors are not sufficiently comfortable with the current methods for determining saving to make larger investments of private capital. Small utilities and states with small populations often find the cost of EM&V to be too expensive relative to their small program budgets. Skeptics of energy efficiency look at the varying savings estimates being reported with seemingly little rationale for the difference and discredit energy efficiency. For these reasons and more, continuing in the current paradigm of EM&V limits energy efficiency's potential, forming a set of barriers slowing expansion much like a "tax" on the growth of energy efficiency.

In assessing the specific activities to undertake, DOE has identified some shortcomings in current practice:

- Inconsistent use of terms and reporting fields (NEEP, 2011).
- Accuracy of conventional gross savings calculations is masked by the use of multiple methods. If a single method were used for each specific measurement task, the actual dispersion of results would be better revealed.
- The costs and timing of gross savings calculation are partly a function of the need to gather data for a significant time. Clear data needs can reduce the time and resources needed to obtain the requisite data, as can clear and detailed calculation procedures.
- Conventional gross savings calculations do not produce the distributions of outcomes that the financial community relies on to develop products; a new approach is necessary.

New Paradigms That Address the Limitations of Current Practice

DOE started three projects to address these shortcomings and help the nation move towards a new paradigm for quantifying energy savings; described below:

Project 1: State Energy Efficiency Action Network EM&V Working Group

In 2010, DOE and the US Environmental Projection Agency (EPA) created the State and Local Energy Efficiency Action Network (SEE Action) to support state and local governments as they pursue energy efficiency[5]. SEE Action contains eight working groups, including one that focuses exclusively on EM&V. Working group members indicated that there was both a need and opportunity to explore improving the determination of gross savings from energy efficiency. Since the Working Group includes stakeholders with multiple perspectives, it serves as a forum in which issues can be examined from multiple viewpoints. Over the last two years, the EM&V Working Group has established priorities, documented in a blueprint (Frisch, 2011), and completed a number of projects.

One project focus is building capacity, for example through an educational webinar series and guide to evaluation. The monthly webinar series[6] is designed for commission, state, or non-profit staff getting started with EM&V. The Model Energy Efficiency Impact Evaluation Guide, first published as part of the National Action Plan for Energy Efficiency and now under revision, provides a framework that organizations or jurisdictions can use to define their own evaluation requirements. It is a companion tool to the Uniform Methods Project (described below); it provides higher level guidance. The Guide includes a revised set of definitions for energy efficiency evaluation terms (in which the multiple viewpoints were particularly important). SEE Action Working Group members are actively working with other organizations to share these definitions, building consistency across the industry.

The Working Group is also tackling complex and persistent EM&V issues. The idea for the Uniform Methods project was born out of group conversation and supported by the Cadmus research reviewing TRMs. Two detailed scoping papers have been completed: (1) examining technical issues that would need to be addressed to support a national EM&V standard and (2) examining the feasibility of national databases for EM&V documents and measure savings. A consistent theme in this work is the need for improved consistency and comparability despite, or perhaps because of, the variety of EM&V stakeholders and different accuracy needs.

Project 2: The Uniform Methods Project (UMP)

One characteristic of the current way we calculate energy savings is that there are a large number of acceptable methods for developing a savings estimate. While there are multiple reasons for this, a quick review of commonly available "protocols" reveals that a number of approaches can be used for any given situation. The result is that if different methods are used to measure savings in similar situations, differences in results may occur simply because of differences in methods. The Uniform Methods Project was designed to test whether more narrowly defined "use cases" of energy efficiency measures could result in general agreement on a single way to calculate savings.

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[5] More information on SEE Action can be obtained at http://www.energy.gov/seeaction/. More information on the EM&V Working Group is available at http://www1.eere.energy.gov/seeaction/evaluation.html

[6] www.emvwebinar.org

For example, traditional protocols for evaluating commercial buildings allow for the use of statistical analysis of energy usage, building energy modeling or a combination of the two. The actual technical approach depends on the needs and budget of those funding the evaluation. But the results of (Schiller, 2011) show that if the methods for calculating savings differ between two energy efficiency programs, one cannot conclude why the results are different. This hampers or prevents comparative analysis between similar programs offered in seemingly similar circumstances. Moreover, determining which results are more "accurate" becomes a separate and challenging question. In the context of a national requirement that could in part be met with energy efficiency, the administering authority, with the power to impose penalties for shortfalls, would not be certain whether shortfalls were real or the result of difference in measurement approach choices.

The UMP set out to see whether the energy efficiency evaluation profession could generally agree on a single approach to calculate energy savings for a single use case. General agreements means that while an individual evaluator may have different personal preference, the evaluator agree the protocol proposed through UMP is a valid way of calculating savings. The UMP also attempts to balance of rigor, cost, and timeliness, not necessarily employ the "best practice," since that usually implies a relatively high cost.

The project began in the fall of 2011. It is organized with a[7]:

- Steering Committee made up of the users of energy efficiency savings results who choose the use measures and use cases for which a protocol is developed; and
- Technical experts who develop a candidate protocol for the specific measure and use case chosen by the Steering Committee.

Several Steering Committee meetings have been held and use cases identified and prioritized. For these technical experts for each have been or are being recruited. The first set of use cases for which methods are being develop includes residential lighting, unitary commercial HVAC, residential refrigerator recycling and residential whole-house retrofits. Methods for another dozen or more use cases are expected to be complete by the end of 2012. All the protocols will be presented to the public for comment[8]. Use of the protocols is voluntary, and Steering Committee members are encouraged to adopt or support the adoption of the protocols. To the extent feasible, the data required in the UMP's protocols will be linked to the same data taxonomy as developed for the next project.

In essence, these protocols, for approximately twenty measures, will be a default standard for use around the country. Their use will provide:

[7] The UMP process is being managed by The National Renewable Energy Laboratory and the technical experts by Cadmus Consulting Group.

[8] This replicates a common practice in the setting of Federal standards.

- A basis for comparison between similar measures completed by different states or utilities;
- Allow limited EM&V resources to be used for more challenging questions of program design and, if the locality desires, attribution of results; and
- A foundation and learning experience from which a national standard for gross savings determination could be built, if needed.

Project 3: Energy Buildings Performance Database (DBPD)

DOE's current interest in EM&V was also sparked by the realization that current gross savings calculations generally do not provide the basic information used by financial institutions to assess portfolio risk and design financial products. The financial community seeks to understand and analyze the risks of energy efficiency finance based on the distribution of savings from a portfolio of projects. Finance today reaches large scale when large numbers of individual loans or investments can be pooled, their financial characteristics defined and repackaged, and the resulting repackaged products are sold or traded in the secondary market. This structure can access investments totaling billions, rather than the millions currently supporting energy efficiency. To gain insights into how this might be done, the Department began an additional project that approaches the measurement question from a different perspective: describing energy usage from an actuarial or statistical approach. This approach was described in Mathew (2005) but little work followed.

This project, the DOE Building Performance Database (DBPD) has reached the stage of a reasonable demonstration tool or pilot. It has the following structure:

- A taxonomy of building characteristics and energy usage data;
- A data layer consisting of buildings with defined characteristics and energy usage; and
- A tool layer allowing extraction of groups of buildings with desired characteristics and analysis tools using that extracted data.

In this beta phase, the data layer contains about 50,000 residential and commercial buildings. These are an eclectic collection of buildings from various sources, mainly publically available, but without the information that would allow the identification of individual buildings. Generally no building is identified more specifically than its zip code; in some cases data providers have required additional safeguards of privacy. Efforts continue to add data, mainly by accessing data from evaluation datasets, which naturally combine energy usage and characteristics for individual buildings. Only actual measurements, either of energy usage, or building characteristics, are included.

Two tools allow database users to select buildings with specific characteristics (e.g. buildings with a high-efficiency device installed compared to those with a low-efficiency device) and compare their weather-adjusted energy usage. Pair-wise differences in usage between the individual members of two building data selections provide the distribution of energy usage changes between the two data buildings. This distribution of energy usage differences, when extrapolated over some period of time, and valued using a user defined energy cost forecast, give the basic data desired by the financial community to assess the opportunity of loans or other financial encouragement.

For example, suppose two data extracts differ only by the age of the buildings. Then the cash flow models a portfolio of loans to each of the older buildings and the event of remodeling them to be like newer buildings. A portfolio distribution like this is a basic data input for financial institutions to develop loan products. The key point is that the calculation of savings is not a number, but a distribution of values from which one can compute means, but also the likelihood that savings will be at some value other than the mean. This provides a more interesting perspective, because the basic data shows the variability of buildings in use, without the analyst having to conduct separate studies of behavior or use.

While the financial industry has generally been supportive (see Rockefeller-Deutsche Bank (2012)), other uses are possible including energy efficiency program design and projections of program savings which would include a full probability distribution of possible gross savings.

The current project has reached a mature "beta" stage and has been demonstrated to financial and other audiences. DOE is considering how best to further develop the DBPD. Data is still being added and DOE is actively seeking data sources willing to contribute building data. DOE is considering enabling third parties to develop tools, and is determining the future location and access of DBPD.

Possible Future Developments

DOE is monitoring two parallel developments to see what impact advanced metering infrastructure (AMI) will have on future gross savings determination. The first is the spread of high-resolution usage data as AMI continues to be deployed across the United States. Already several commercial applications are under development using this data to remotely assess energy efficiency opportunities. Because the data at hourly or even finer resolution can carry information about the actual equipment and its operation, it is possible to remotely develop simple baseline models of less complex building types. An example of this is the work being done by the firm "First Fuel"[9], but there are others.

Given that is it possible to build a benchmark, or base-case, model of a building's energy use remotely, it is not too great a stretch to continue to monitor building energy use after a retrofit or significant equipment upgrade. This would provide the ability to assess whether the initial prediction of energy use change has occurred. This provides both an actual measurement of gross savings, as well as a validation of the predicted energy savings. Further, since the base-case predictive model of savings can be simulated over shorter periods than a year, this validation of the model's savings could be done over shorter time periods than the full year currently regarded as the minimum time to gather data for gross savings calculations. While these part-year validations would be incomplete, they still would provide an indication whether

[9] See http://www.firstfuel.com

the savings prediction was "on track" or not. Thus in a few quarters or even months, it could be possible to begin to assess whether expected savings will be realized.

Thus this approach begins to open the possibility of gross savings determination in time frames significantly less than a year, and at significantly less cost than current methods.

The other development, also driven by new technology, is the prospect that equipment (or buildings) will be able to self-monitor energy performance. Consider the increasing prevalence of "smart" technology in equipment from residential clothes washers to major building systems (lighting, HVAC, or the building control system itself). Generally the "smart" technology is focused on operational characteristics. But given that such a high degree of "smart" capacity will be build into such technology, it probably only requires a few sensors, the addition of connectivity and some modest programming in the form of simple calculations and suitable safeguards on information access for such equipment to be able to monitor whether it is, or is not, within its energy performance specification. For such equipment, the measurement of gross savings at the simplest level amounts to receiving from it its actual operating schedule and whether it is, or is not, operating within its energy performance specification.

For example, consider a utility proposing to subsidize the replacement of existing rooftop air conditioning units on big box retailers. Currently such units are 11 SEER or less and generally rated at 10 tons. The newest units are 18+ IEER and contain substantial self-monitoring capability. To validate gross energy savings, the installed units could be remotely queried as to their operating schedule and whether their energy performance is at or above their rated efficiency. Using a baseline of 11 SEER, a gross savings can be readily calculated. Again, the calculation can cover the period of operation: a month, quarter or even a year. This could provide a quick, and low cost validation of gross savings far quicker and at far less cost than current gross savings methods.

For both of these approaches, the DOE will be monitoring market developments and considering research or demonstration projects to further the development of quick, low cost accurate gross savings determination.

Conclusion

SEE Action EM&V activities, the Uniform Methods Project, and the Buildings Performance Database address EM&V issues using different and complementary approaches. SEE Action is convening stakeholders and providing a forum for resolution of many different EM&V challenges. The Uniform Methods Project provides standard approaches to calculation of savings from efficiency measures. The Buildings Performance Database aggregates detailed building level data into distributions, supporting the financial industry's data needs and providing augmented information to the EM&V community. Combined with other pending advancements, these projects will lead to a paradigm shift that will help to streamline and improve the quality of EM&V, facilitating scaled-up investment in energy efficiency.

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