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LLNL-TR-436013

LLNL Preliminary Assessment of the CPUC EM&V Program

June 2010

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Lawrence Livermore National Laboratory is operated by Lawrence Livermore National Security, LLC, for the U.S. Department of Energy, National Nuclear Security Administration under Contract DE-AC52-07NA27344.

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Abstract

At the request of Commissioner Dian Grueneich, Lawrence Livermore National Laboratory (LLNL) has reviewed the Evaluation, Measurement and Validation (EM&V) practices of the California Public Utility Commission (CPUC) Energy Efficiency (EE) Program. LLNL's examination was performed through reviews of documents written by the CPUC, namely decisions, rulings, and Energy Division staff reports, as well as other reports written by experts in energy efficiency. From our investigation to date, we have found three key findings:

- The CPUC approach to Energy Efficiency has helped the state obtain some reductions in energy use
- The current EM&V and Risk/Reward Incentive Mechanism (RRIM) is designed in a way that makes it virtually impossible for the state and the Investor Owned Utilities (IOUs) to know what the expected outcome will be of annual energy efficiency investments. This is in part due to the changes to the EE program mid-cycle, and in part due to the lack of a scientifically valid, consistent way of estimating energy savings.
- Redesigning the approach and accountability of the EM&V program and the RRIM can greatly improve the process, reduce disputes, and further increase energy savings. One key factor of a program redesign would incorporate a consistent, transparent mechanism to estimating energy savings, based on a scientific approach.

This document outlines our general findings from our preliminary investigation. We have identified and consolidated the intrinsic problems and issues that currently reside in the EM&V and RRIM mechanisms. The next step in our involvement would be to assist the CPUC in restructuring the program to enhance the overall value to the State.

An overview of the CPUC EM&V program can be found in Appendix A. A list of parties interviewed, as well as an Overview of approaches to Verification and Validation can be found in Appendices B and C, respectively.

Introduction

At the request of the California Public Utility Commission (CPUC) Commissioner Grueneich, Lawrence Livermore National Laboratory (LLNL) conducted an informal review of the CPUC Evaluation, Measurement and Verification (EM&V) process. This white paper addresses concerns raised by participating parties as to the validity of overall estimates of energy savings derived from the EM&V program. LLNL focused on the present and prior disputes between the Investor Owned Utilities (IOUs) and the CPUC Energy Division (ED) regarding the estimated energy savings, and therefore the payments due the IOUs under the CPUC's Risk/Reward Incentive Mechanism (RRIM). This review assessed the validity of the EM&V program for a) assessing the total energy savings from the Energy Efficiency (EE) program, b) assessing the energy savings from individual types of measures so that the design of energy efficiency programs can be improved, and c) the validity of the EM&V estimates in supporting the RRIM.

Our assessment was performed through reviews of the documents written by the CPUC, namely decisions, rulings, and Energy Division staff reports, as well as other reports written by experts in energy efficiency. We also performed a series of interviews with relevant stakeholders in the EM&V process, including CPUC ED staff, IOU EM&V managers, and academic experts..

This report focuses on the 2006–2008 cycle, with the understanding that there may be substantive changes to the EM&V and RRIM processes for the 2010–2012 cycle.

Objectives of LLNL Review

The staff at LLNL (LLNL) conducted a preliminary investigation of the CPUC EE program,[1] focusing on the EM&V and RRIM components. We aimed to assess the ability of the 2006-2008 EM&V program (and the nascent 2010-2012 program) to support the objectives of the overall EE goals and related directives. In doing so, we aimed to identify areas where structural reforms could improve the EM&V program. Following our preliminary assessment, we identify future lines of inquiry to identify ways to strengthen the EM&V processes.

California's Record of Energy Efficiency

Since the 1970s, California has been a leader in using Energy Efficiency (EE) as a method to reduce the amount of energy needed, while creating jobs and spurring innovation (Roland-Holst 2008; CEC 2005). According to the "Draft 2006-2008 Energy Efficiency Evaluation Report," dated April 15, 2010, the most recent EE cycle has resulted in energy savings equivalent to 2.6 $MTCO_2$. The long-term evidence of these programs has been a relatively constant per-capita energy use, commonly referred to as the "Rosenfeld Curve," named after Art Rosenfeld, former CPUC Commissioner. While some research hesitates to attribute all of the energy savings in the state to Energy Efficiency programs (Sudarshan and Sweeney 2008), it is clear that California has saved more energy over the past forty years relative to other states in the union.

1. For consistency's sake, we refer to the totality of the CPUC EE efforts (including the IOUs, Energy Division, and Consultants), as the "CPUC EE Portfolio". Each IOU runs its own IOU EE "Portfolio", which is composed of multiple smaller programs. The CPUC Energy Division (ED) EM&V efforts, performed by ED staff and their evaluators and consultants, is referred to as the "EM&V Program".

Contributions from entities such as the CPUC to this effort are critical through policy settings and incentives for the IOUs.

The Use of EM&V

Performing Evaluation, Measurement and Verification on EE programs help assess their performance toward reaching strategic goals. For the EE Program, Measurement and Verification generally refer to the energy savings estimates of individual "measures", or deployed technologies, and Evaluation refers to a portfolio- or program-level assessment. A number of technical, scientific and statistical approaches can be used to perform EM&V; some new data sources, like the use of Smart Meters, may provide more data points and a more complete analysis. Currently EM&V at the CPUC process lacks scientific rigor and technical expertise to assess the complex nature of energy savings and the associated uncertainty. A strong, scientific grounding of measurements and modeling uncertainty are required for such a complex and dynamic system.

Finding 1
The CPUC EE program has been successful in reducing energy use in the State. An EM&V program is a necessary component for the assessment of those savings. The current approach to EM&V is lacking in scientific and technical engineering rigor in its deployment.

Validity of the Current EM&V Program Structure for CPUC's Objectives

The measurements and processes for evaluating savings contain some uncertainty. It is common to have uncertainty associated with this type of measurement activity and normally it is formally incorporated in the analysis and decision making process. The current EM&V program does not incorporate uncertainty in its processes, thus causing disputes. The essential question is whether they are adequate for their purposes, and, if not, can they be improved?

The CPUC EE EM&V Program has two fundamental objectives:

- Evaluate the performance of the EE Portfolio.
- Evaluate IOU performance to determine its compensation

We found that from our preliminary investigation that the EM&V process, as designed, is a valid approach to evaluate the performance of the IOU EE Portfolio. However, the EM&V process, as implemented, is not a valid approach for determining the IOU compensation.

In the following sections we discuss the key shortcomings of the measurements and the process, and discuss the validity of using them to meet the CPUC's objectives.

EM&V, RRIM, and IOU EE Programs

In our analysis, we have found numerous structural and implementation problems that have led to the disconnect between the purpose of EM&V and the RRIM from the IOUs' maximizing energy savings.

Finding 2
The way the EM&V program is applied to support the RRIM does not lend itself to efficient incentives for the IOUs, and can be expected to encourage disputes.

We have observed that, for the most recent cycle, there was a practice of changing the parameters, models, and assumptions used to evaluate the energy savings during the cycle. This exposes the IOUs to further artificial risk that does not contribute to meeting the CPUC's goals.

The way that risks are assigned between the CPUC and the IOUs appears to undermine the program. The RRIM can be viewed as a contract between the CPUC and the IOU. The current arrangement is structured as a "performance specification contract"; that is, the IOU is expected to design and execute a program to achieve a specified level of performance (e.g., a level of energy savings). This is contrasted with a "method specification contract" in which the contracting entity (CPUC) specifies work to be done and the contractor (IOU) is required to perform specified actions (e.g., make a certain number of installations of a certain type). The risks and responsibilities of the parties are quite different in these two types of contracts.

A "performance specification" contract is best used when the contracting party (the CPUC) *does not* have the knowledge and skills needed to determine how to best reach its project goals, and the contractor (the IOU) *does* have the knowledge and skills. In such a situation, the contractor is taking on a risk that it is well equipped to manage. The "method specification" contract is best used when the contracting party does understand how to reach its goals, and simply wants the contractor to carry out the needed work to implement the elements of the plan. In this case the contracting party assumes the risk for determining the best actions to attain the goals; the contractor assumes only the risk associated with actually implementing the actions.

Overall, IOUs appear to face risks that are not in their control. The measurements and estimates of energy savings are made with varying degrees of care by the EM&V evaluators. There might be very detailed modeling and analysis, or something that is very approximate. There are changes in the basis for measurements from beginning to end of the cycle, particularly from the DEER database, and ongoing changes in the building energy models. In addition, there is uncertainty about the way that an installation or building might actually be used or operated after the installation.

Finding 3
The process for changing the EM&V rules is opaque.

During the cycle the ED staff and the contractors can change the parameters and models used for evaluation. However, this is not done in an open way with clear proposals, counter-arguments, and a clear record of the discussions and decisions. It has been pointed out that in the past such changes were made through an on-the-record process in which claims by any party could be challenged and, therefore, had to be defended by clear, on-the-record responses. Although the process was cumbersome, the logic and supporting data leading to each decision were clear. In the current process there are workshops and discussions, but they are not necessarily rigorous. In addition, the parties can submit comments to the ED regarding the way measurements are made. However, the ED is not required to fully explain its logic in making its determinations.

We found that the 2006–2008 mechanism for discussing disputes was unsatisfactory to most parties involved; the 2010–2012 solution, as deliberated on by the Commissioners, may not end with significant changes in this sentiment. Overall, the IOUs cannot control these factors, thereby introducing considerable risk to their business operations.

Finding 4
Changes in the rules during the cycles change both the estimates of energy savings and the compensation to the IOUs. This can create questions about the integrity of the process.

The IOUs create their estimates of savings from the DEER database, then create their programs based on those estimates (for the last cycle, the IOUs used the 2005 DEER database). However, the CPUC has determined that the *ex post* evaluations used for the RRIM should be made using current information rather than the *ex ante* information that the programs were initially designed from.

This can put the IOU in a detrimental position; as more data becomes available on the performance of individual measures, there is the increased likelihood that the IOU estimates of savings will not contribute to their reaching their goals. This is further compounded by the fact that the building energy models (DOE-2, eQuest) have been modified over the course of the cycle; the evaluators are in a sense measuring a different deployment from the IOU.

In principle the rules are only changed to provide better energy savings measurements. However the fact that a rule changes, made during the cycle, will affect IOU compensation during that cycle can raise the concern that IOU compensation entered into the decision. This problem arises due to the fact that changes are made during the cycle and due to the fact that the process for changing the rules is opaque.

Finding 5
The ED staff has been saddled with incompatible obligations.

The CPUC ED staff directs the EM&V work and manages the contractors (or "Evaluators") doing the EM&V. Thus the staff is responsible for any changes in the EM&V process. At the same time, the staff is responsible for resolving disputes about the results that come out of the process they have created. This can put them in the awkward position of having to second-guess a position they had taken earlier.

The problems we observed with the process stem from two fundamental causes: 1) The EM&V rules are changed during the cycle and can affect the compensation to the IOUs and 2) the process for changing the EM&V rules is not open and well documented. It seems that both of these problems could be remedied while retaining a vigorous and effective energy efficiency program.

Proposed Next Steps for EM&V Program Improvement

In our preliminary investigation, we assessed some of the fundamental problems with the CPUC EM&V program and the associated RRIM. The system, though flawed, is not "broken". Rather, it can be improved through a process of analysis, feedback, and stakeholder buy-in.

Finding 6
Redesigning the approach to EM&V and incentivizing the IOUs will assure continued savings from energy efficiency and assure EE Program achievement.

LLNL views itself as a valuable contributor to that process. To further our investigation, LLNL can:

1) Research further the current (and nascent 2010–2012) EM&V cycles, focusing on the legal constraints, the balancing of risk, and the capturing of uncertainty
2) Develop a path to an improved EM&V process, with a less contentious RRIM
3) Examine the interplay between IOU EE Program design, revision, and implementation with ED staff and CPUC rulings.
4) Reevaluate the paradigm of energy efficiency, and develop approaches to create robust, achievable goals.

To pursue these tasks we believe that the following steps would be useful.

- Examine the overall structure of the program more rigorously
  - Define the objectives of the EE program and an operational way of measuring the accomplishments
  - Identify fundamental activities within the program. Not necessarily activities as they are currently structured, but as they are intended and designed.
  - Define the purpose of each component of the process

  - Identify the information needed by each activity, including the appropriate format and level of accuracy

- Identify methods of tracking activities, storing and logging data, taking advantage of current technology.
- Identify and construct scientific standards and approaches to measuring energy savings, while accounting for the embedded uncertainty in the system.
- Examine the incentives and risks inherent in the structure of the RRIM. Identify alternative structures that would more efficiently allocate risks and incentives between the parties. These include processes that:
  - Reward the IOUs for the deployment of measures, according to a predetermined, scientifically valid payment schedule
  - Give the IOUs a "total energy savings goal", and allow them to structure their programs as they see fit, to maximize profit
  - Separate near-term and long-term energy savings goals as separate programs
- Identify ways that the expertise of the parties can be brought together to continually improve the design of programs.
- Investigate ways to address the broader objectives of the program (e.g., market transformation).

Appendix A
Logic and Structure of the Current EM&V Program

Objectives of the CPUC's EE Program

The CPUC Energy Efficiency program is intended to "motivate the IOUs to develop and continuously expand EE programs on behalf of their customers" (EE Strategic Plan). The EM&V process is intended to accurately measure the energy savings of various types of EE measures. These results are used to design future programs so any changes have a lasting impact on future program designs. The EM&V program is also used to evaluate IOU performance to determine their compensation.[2] The process performs the following tasks:

1. Evaluation of the CPUC EE program as a whole in contributing to the state's EE goals (and ultimately reducing the number of new power plants needed)
2. Evaluation of the IOU Programs towards reaching specific energy savings goals
3. Evaluation of specific technology and measure impacts
4. Evaluation of the IOU Programs in implementing their programs
5. Determine the repayment/penalty schedule for the IOUs for their running the EE Programs, as established by the Risk Reward Incentive Mechanism (RRIM)

Organization of the EM&V program

The program is executed in three-year cycles. Energy savings goals are set at the start and the IOUs design programs to meet the goals. During the cycle, IOUs implement the program and estimate the energy savings achieved each year. Under the RRIM, they are compensated for the savings that they estimate. At the end of the three-year cycle, the CPUC ED makes a separate, final estimate of energy savings. This final estimate is used to determine the final payment or penalty to the IOUs.

The program is structured so that each participant has specific roles, tasks, and responsibilities (see Figure 1). The CPUC (through its Commissioners and Administrative Law Judges) sets the EE goals for each three-year cycle, and determines the responsibilities of the ED. The CPUC Commissioners also will be determining the ultimate ruling on the RRIM for the IOUs.

Roles and Responsibilities

The IOUs design their programs around the goals and directions from the CPUC Commissioners, incorporating some recommendations from the ED staff, and then contract Consultants to implement them. The IOUs also deliver annual estimates of energy savings from the progress of their programs and collect interim compensation as possible rewards from their actions.

2. Decision 10-04-029

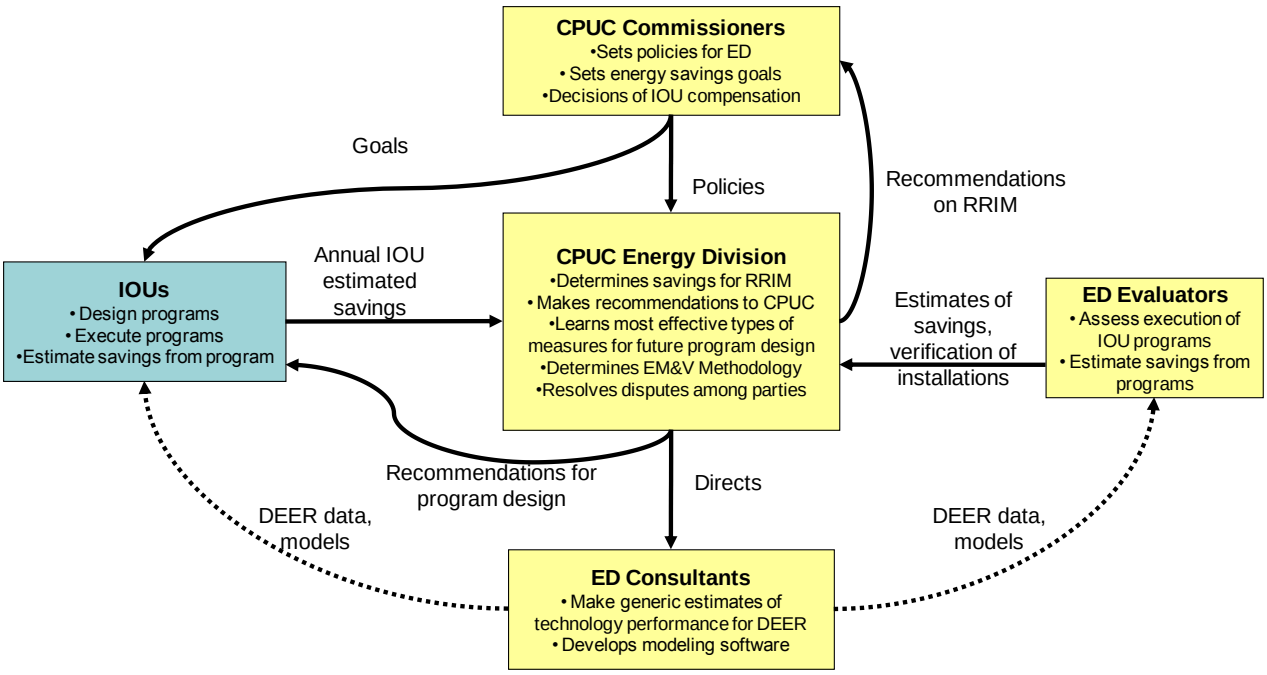

Figure 1: Process of Evaluating Energy Savings

The ED runs the EM&V program, hires evaluators to conform to the protocols, and collects data on the IOU programs. The ED also hires consultants to develop building model software, and determine numeric estimates used in the program for utility evaluation (i.e., DEER). A fair degree of responsibility is laden upon the CPUC Energy Division. They structure the EM&V of the IOU programs and perform the following tasks[3]:

- Measure and verify energy and peak load savings for individual programs, groups of programs and at the portfolio level
- Generate the data for savings estimates and cost-effectiveness inputs (DEER)
- Measure and evaluate the achievements of energy efficiency programs, groups of programs and/or the portfolio in terms of the "performance basis" established under Commission-adopted EM&V protocols
- Evaluate whether programs or portfolio goals are met

As stated in Decision 07-09-043, the ED also has the responsibility of resolving disputes about the EM&V process and results. It is apparent that the ED both determines the process for measuring Energy Savings, and resolves disputes about the process. This is a concern mentioned by the IOUs, which they deem a "conflict of interest".

It should be noted that both the ED and the IOUs perform more in a supervisory role and that consultants and evaluators implement measures and capture data in the field for the IOUs and the CPUC ED, respectively.

3. CPUC Decision 05-01-055, p. 12

To determine Energy Savings, the cornerstone of the EM&V process, estimates are made, for each measure installed, of the difference between what energy would have been used with the old technology (the "counterfactual conditional"), and the forecasted energy use with the new measures installed.

At the end of the first and second years of the cycle, the utilities estimate the savings from the implementations of their portfolios. This is called the "ex-ante estimate".

The ED staff, in turn, reviews the ex-ante estimates from the IOUs at a portfolio level, and hires a number of evaluators to review specific IOU programs as for their efficacy. The evaluators determine a "verified" estimate of energy savings, called the "ex-post estimate". The ex-post estimate was intended to determine the degree of IOU compensation in the RRIM. The IOUs as well as other parties can comment on the evaluator and ED reports as to their validity and accuracy. Most of the comments have focused on the numeric difference between the ex-ante and the ex-post estimates, and the methods for their determination. In both the 2006–2008 and the 2010–2012 cycles there is no formal process to resolve disputes on the record. While the 2010–2012 cycle has more clear resolution to dispute resolution, it is not a transparent process.

Other factors, such as Net-to-Gross (NTG), Estimated Useful Life (EUL), and interactive effects of measures are also estimated and affect the net energy savings for each portfolio. But these have secondary importance relative to net energy savings.

After the ED reviews the comments, CPUC Commissioners make the final determination of the disposition of disputes regarding the RRIM.

Methods for Estimating Energy Savings

The EM&V process estimates both the energy use by each individual measure and the energy that would have been used in the absence of the measure (the counterfactual conditional). The estimated energy savings is the difference between these. Energy use and savings estimations can be estimated in four different ways.

1. **Measurement**. The energy use of various technologies, either new or old can be measured either in test centers or in-situ installations.
2. **Models**. Using standard building energy models, the energy use or savings due to a specific measure can be modeled in a specific building, accounting for the construction, location, and use of the building and its equipment.
3. **Averages or typical values**. Using standard building energy models, the energy use or savings due to a specific measure can be modeled for a set of standard building types, geographic locations (climates), and standard performance. This is the approach used by the DEER database
4. **Standards**. Using building codes and standards, the impact of a specific installed measure can be estimated as a derivation from the current code. For example, for a new building in California built today, using a specific high-efficiency chiller could help the building use a specific percent better than the Title 24[4] code for that building.

[4] CEC-400-2008-001-CMF

For the 2006–2008 cycle, the ex-ante estimates made by the utilities were primarily done using models and averages, with a few examples of measurements (the IOUs are only permitted to perform limited product evaluations as the CPUC believes them to be conflicts of interest). The estimates were drawn from the 2005 DEER database (averages), when available, and site-specific building energy model results (called "work papers"), when averages were unavailable. In contrast to the utilities, the ED evaluators used measurements, models, and averages in generating the ex-post estimates. The decision as to which estimate was used depended on whether the installed measure was a "High Impact Measure" (HIM, having a disproportionate impact on energy savings due to its energy savings potential), the "reliability" of the IOU estimate, and whether a DEER estimate was available or relevant.

It should be noted that for the "Draft 2006-2008 Energy Efficiency Evaluation Report", the ED used the 2008 DEER estimate, which contains different energy savings estimates from the 2005 estimates.

Other estimates relevant to the EM&V process, like EUL and NTG followed similar paths; however, due to their significance in the EM&V process, we have focused our investigation on energy savings.

As of this writing, the method of determining the RRIM has not been determined for the 2006–2008 cycle (nor the 2010–2012 cycle). The CPUC Commissioners will be evaluating at least nine separate combinations of parameters (called "scenarios") as to the most appropriate to use for IOU compensation.

Uncertainties and Estimation Errors

The processes of making the EM&V measurement will inevitably contain estimation errors. This does not imply that the estimate includes mistakes. It simply recognizes that the true savings cannot easily be estimated accurately. Measurement uncertainties exist due to the variable nature of building equipment performance and operation. When comparing the IOU energy savings estimates with that sampled by the evaluators, the numbers will most certainly differ for each installed measure. This due to a number of reasons; for example:

- Facility management and installation techniques are not consistent from planning through implementation
- Weather varies from year to year; the sampled time period may not be representative of actual energy use
- Due to economic shifts, building use, and occupancy, rates may be different from originally estimated by the IOU

It is clear from the protocols, activity, and reports by the evaluators that they do attempt to make statistically valid samples.

Also, measurements made based on models may be based on detailed models or generic models. Measurements based on averages may be quite far from the true value for that particular installation. We do not have data on the *variance* of the values in DEER

Appendix B
List of Interviews Conducted in Investigation

LLNL conducted in-person interviews with key individuals from the following organizations:

- Pacific Gas and Electric
- Southern California Edison
- San Diego Gas and Electric
- Southern California Gas
- University of California at Berkeley's Energy and Resource Group
- CPUC Energy Division Management and Staff
- Natural Resources Defense Council (NRDC)*
- The Utility Reform Network (TURN)*

* Indicates interviews planned

Appendix C
Concepts of Evaluation, Measurement and Verification

The primary purpose of the evaluation, measurement and verification (EM&V) program administered by the CPUC is to evaluate the energy efficiency programs implemented by the IOUs and verify the resulting energy savings and demand reductions. In order to accomplish these goals, a methodology that provides a high level of confidence in EM&V program estimates is required. A verification and validation (V&V) program based on standard practices can provide such a tool.

In order to assess what should be included under the scope of verification and validation, it is useful to begin with definitions of the EM&V components:

> **Verification**: The process of determining that a computational model accurately represents the underlying mathematical model and its solution (ASME 2006).
>
> **Validation**: The process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model (ASME 2006).

Analysis of these definitions reveals that verification is focused on determining whether any tools built correctly implements the chosen mathematical model while validation addresses whether or not the conceptual and mathematical models represent the reality of interest. Taken as a whole, V&V is therefore a process for "accrediting" the output of analyses for a specific set of conditions and a specific purpose.

With these definitions in mind, it is critical to note that a model and a set of data that has gone through a verification and validation process do not necessarily produce output that can be considered V&V'd. In order to provide the required level of confidence, the program must therefore look at data, measurements, models, model outputs and analyses as a whole.

Comparison of EM&V Program to Standard V&V Concepts

In order to understand how verification and validation will be performed in the context of the EM&V program, we first examine the definitions associated with evaluation, measurement and verification:

> **Evaluation**: The performance of studies and activities aimed at determining the effects of a program, or any of a wide range of assessment activities associated with understanding or documenting program performance or potential performance, assessing program or program-related markets and market operations, or any of a wide range of evaluative efforts including assessing program-induced changes in energy efficiency markets, levels of demand or energy savings, and program cost-effectiveness (The California Evaluation Framework, p. 421).
>
> **Measurement and Verification** (M&V): The process of using measurements to reliably determine actual savings created within an individual facility by an energy management program. Savings cannot be directly measured, since they represent the absence of energy use. Instead savings are determined by comparing measured use before and after

implementation of a project, making appropriate adjustments for changes in conditions (IPMVP Concepts and Options, p. 5).

With this understanding, we can make the following observations:

- The EM&V concept of measurement and verification encompasses aspects of both verification and validation in that "using measurements to reliably determine actual savings" (IPMVP Concepts and Options, p. 5) cannot be achieved unless the methods of calculation are first determined to correctly implement the conceptual model (verification) and that they measure what they are intended to measure with the required level of accuracy (validation).

- The EM&V concept of evaluation used to achieve "understanding or documenting (of) program performance" (The California Evaluation Framework, p. 421) implies a level of documentation is required. While the definitions of verification and validation do not discuss documentation directly, to build confidence in the program, it is critical that all V&V activities be well documented so that they are repeatable and open to independent review.

- The EM&V definitions do not directly address the concepts of data and model validation, but rather focus on the output of the process. While it may be implied that it is not possible to gain the required understanding without validated data and models, this concept should be explicitly included in any V&V plan.

Critical EM&V Components

As discussed above, the V&V process should be considered at all stages of the EM&V program lifecycle, including:

- Setting of program goals
- Development of program data sets
- Conceptual model selection
- Development of analysis tools
- Data collection
- Estimation of energy savings
- Comparison of estimates to program goals

To address V&V throughout the lifecycle, the following program elements should be included:

1. **Data management**: How will data be archived and provided to end users? How will deviations from accepted values be approved?

2. **Statistical sampling**: How will sampling be performed?

3. **Uncertainty quantification**

    - Model selection: How does the choice of conceptual model and model formulation impact uncertainty? Are certain variables included or excluded? What impact does the functional forms of equations have on uncertainty propogation?

    - Input parameter values: What is the uncertainty (and variability) associated with a particular parameter estimate? Does it vary by time of year or location? Is the process by which the value is determined also V&V'd?

    - Sampling: How does sample size and composition affect uncertainty?

    - Measurements: What is the uncertainty (and variability) associated with a particular measurement? Does it vary by time of year or location?

    - Program output: How does uncertainty in the above influence uncertainty in the program output?

4. **Extrapolation issues**: How will sampled data be extrapolated to full-year energy savings?

5. **Verification and validation**: How will V&V be performed as it applies to:

    - Models

    - Data

    - Analyses

6. **Statistical methods for comparing program estimates with program goals:** Given uncertainty in program outputs, what is the acceptance criterion for establishing goal attainment?

Addressing Uncertainty in the EM&V Programs

Without a defensible and comprehensive approach to analyzing the impact of uncertainty on energy savings estimates, it is not possible to make meaningful comparisons and determine the degree to which program goals have been met. As outlined above, uncertainty in program estimates arise from a variety of sources including model choice, parameter uncertainty, and measurement error. Given an understanding of uncertainty, statistical methods must be employed to determine the degree to which it is possible to say that a program goal has or has not been met. Given this uncertainty, and program estimate is just that, a point value which is an approximation of the true (and un-measurable) value.

Standard statistical techniques such as confidence intervals, based on the point estimate and associated uncertainty, can provide an interval that is likely to contain the true value, and the

width of the confidence interval therefore provides some information as to the reliability of the estimate. If the program goal falls within the confidence interval of the program estimate, then the goal can be said to have been met with a given level of confidence. An EM&V program that addresses uncertainty explicitly is more likely to be accepted by interested parties.

V&V Documentation

The primary method of producing transparency is thorough documentation of all program activities. The V&V program to be developed by LLNL will rely on a core set of documents that will address the following issues:

1. Requirements Document
    - What is being measured
    - What metrics will be used to measure it
    - What is the required accuracy of the measurements
    - How much uncertainty is acceptable
2. Specifications Document
    - How will the measurement be performed
        - What equipment will be used
        - What is required training for those taking measurements
    - How will uncertainty be addressed and presented
3. Parameters Document
    - What are the model parameters
    - What parameter value will be used
    - What is the process for deviating from program-accepted parameter values
4. V&V Plan Document
    - What V&V activities (tests) will be performed
    - What are the acceptance criteria
5. V&V Execution Document
    - What was done
    - What models and versions were used

- Outcome of acceptance tests

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