research/into/action inc

Final Report

Research Supporting an Update of BPA's Measurement and Verification Protocols

Funded By:

BONNEVILLE POWER ADMINISTRATION

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We want to thank Todd Amundson, our BPA project manager, for his support and consultation during this project. Our team is also grateful for the time BPA staff and BPA customer utility staffs have taken to respond to our questions about BPA Measurement and Verification (M&V) practices, and to the various organizations that have developed M&V protocols and made them publically accessible so that we could access them for this review. The names and publications of these organizations can be found in Appendix A.

Finally, we thank Laurie Lago of Business Service Bureau for her able assistance in producing this document.

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ES EXECUTIVE SUMMARY

Research Into Action, Inc. and a team of experts in the measurement and verification (M&V) of savings for energy efficiency and demand response projects have conducted a review of current M&V practices at Bonneville Power Administration (BPA). We conducted this review at the request of BPA in connection with release of the *Draft Sixth Northwest Power Plan* (Sixth Plan) of the Northwest Power and Conservation Council (NWPCC), which forecasts a need to increase the region's implementation of energy efficiency measures. Increased energy savings acquisition necessitates an increase in savings assurance activities, including M&V.

In a first phase, BPA has requested we review its M&V site-specific protocols in reference to national best practices in M&V, as well as to the sectors and activities targeted by BPA's resource acquisition activities, and make recommendations for revising and augmenting the protocols. This report details our findings, conclusions, and recommendations from that review.

In phase two of the research contract, we will revise existing and/or develop new M&V protocols for BPA's consideration.

SUMMARY OF METHODS

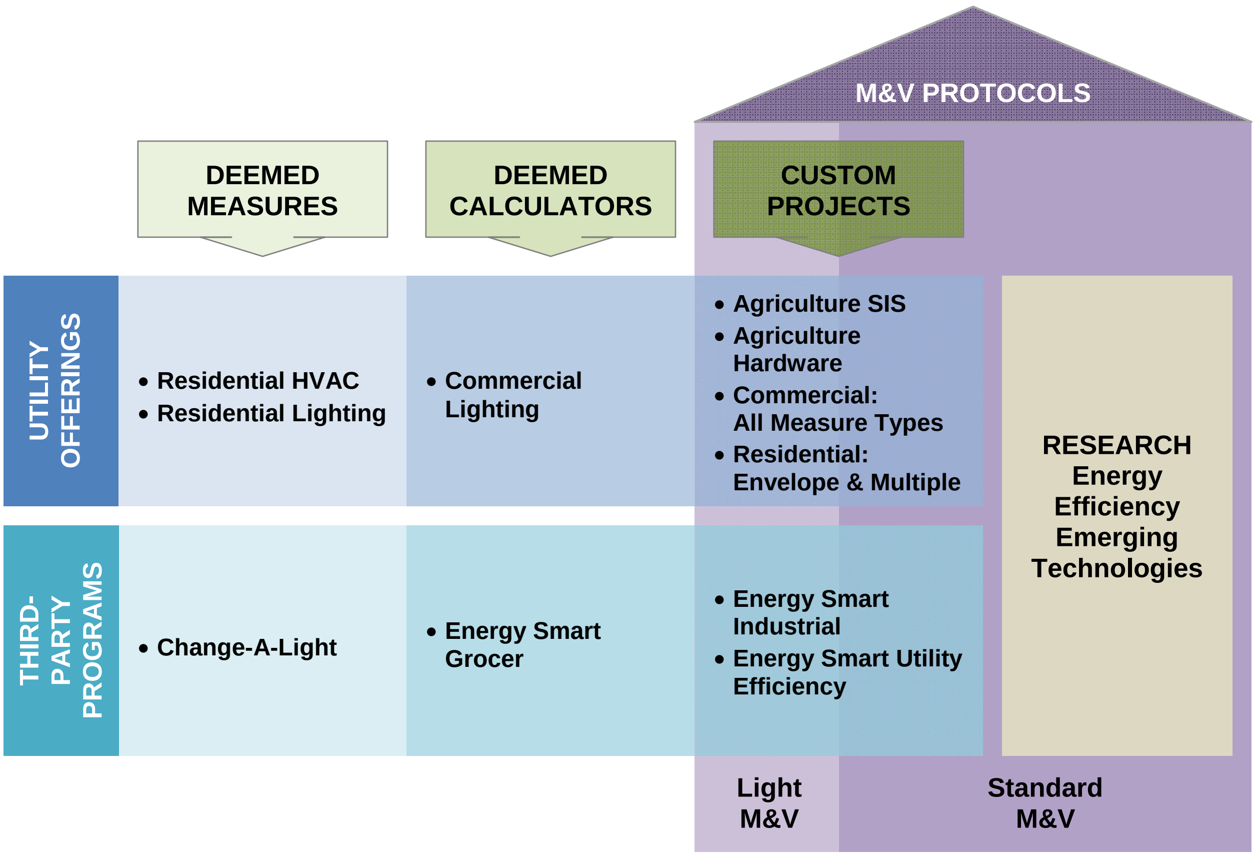
The research summarized by this report comprised:

1. Interviews with 25 staff members of BPA, its customer utilities, and NWPCC to understand how BPA currently conducts M&V, and how well the process works;
2. Analysis of BPA's custom project database by measure type and energy savings;
3. Assessment of M&V protocols used by other program administrators and regions to identify the components of best practices for possible inclusion in BPA's procedures; and
4. Examination of BPA's existing M&V protocols in comparison with best practices, contacts' experiences, and BPA's efficiency resource acquisition.

SUMMARY OF FINDINGS AND CONCLUSIONS

Figure ES.1 illustrates the role of M&V protocols in assuring energy savings from BPA's efficiency activities. The figure shows two horizontal paths to illustrate the energy efficiency acquired by BPA's customer utilities under the *Conservation Rate Credit and Energy Conservation Agreement* and acquired by programs implemented for BPA by third-party implementation contractors. From left to right, the figure illustrates a progression of increasingly resource-intensive savings assurance methods: measures with deemed savings; measures with deemed savings estimation calculators; and all other measures, which BPA classifies as custom projects and assures through M&V conducted in accordance with its site-specific M&V protocols.

Figure ES.1: Programmatic Purview of BPA's M&V Protocols



The region's M&V engineers, many of whom are staff of BPA, can use the Light M&V Plan for projects with expected annual energy savings of less than 200,000 kWh per year. The Light M&V Plan corroborates the measure installation and operation, as well as the engineering calculations underpinning the pre-installation savings estimate, but does not include post-installation monitoring over time or the development of a post-installation savings estimate. For projects larger than the 200,000 kWh threshold, engineers must use the appropriate measure- and site-specific standard M&V protocol.

Among the significant findings of our research are those facets of BPA's M&V activities about which we remain unable to comment. These include the proportion of projects eligible for Light M&V, yet for which the M&V engineer followed a standard M&V protocol, and the proportion of BPA's total custom project savings measured and verified with each protocol. We pursued both of these analyses, but the data provided by BPA were insufficient for us to estimate these proportions.

We undertook the proportional analyses to address one of BPA's research questions for the current work: to recommend an appropriate kWh threshold for the Light M&V Plan (either confirming the choice of 200,000 annual kWh or recommending a new value). Unfortunately, the determination of a threshold as "appropriate" does not derive from experience or best practices, but must rest on the analysis of the projects themselves. For this, it is necessary to conduct a risk analysis, considering: the individual project size; the proportion of total portfolio savings comprised by all projects of that type; and the variation in pre-installation savings estimates from the post-installation estimates. In response to the initial draft of the current report, BPA now plans to pursue this research under a separate contract.

Our research has found that BPA's site-specific M&V protocols are generally working well from a process perspective, and contacts have confidence in the measured and verified savings. Nonetheless, there are opportunities for revisions to bring the protocols into closer alignment with M&V best practices, as we detail in our recommendations, below.

As BPA anticipated in its RFP for this research, the region would benefit from having additional protocols, as recommended. Based on our review and interviews, there appears to be a need to articulate to BPA staff and utility customers the reasons for conducting M&V, the expectations for rigor, and the standards by which M&V is conducted.

While satisfaction with the site-specific M&V protocols is high, contacts expressed considerable dissatisfaction with BPA's current approach that designates as custom many projects, thus requiring the conduct of M&V (and in particular, the Standard M&V Plan, in contrast to the Light M&V Plan) on a high proportion of projects. In addition to the significant effort (and thus cost) this approach entails, and the barriers it poses to utility and end-user efficiency efforts, the approach also necessitates a cadre of experienced engineers. Contacts note these engineers typically are at one or the other end of the career spectrum – approaching retirement age or as new entrants to the field – yet BPA's current approach relies more on individual expertise than a codified, transferable body of knowledge. Consistent with all of these critiques, contacts also expressed dissatisfaction with the limited availability of deemed savings calculators.

Thus, contacts are in general agreement that the region would benefit from efficiency savings assurance measures that decrease the proportion of projects requiring the Standard M&V Plan and increase the proportion governed by the Light M&V Plan, deemed savings estimation calculators, and deemed savings.

Finally, we have reached the conclusion that BPA will best attain its objectives for assuring energy efficiency savings while reducing the burden of M&V by evolving in tandem its M&V policies and procedures, and its evaluation strategy and activities. Through a combination of M&V and evaluation activities conducted over time, BPA can better understand the risk attending the various efficiency activities, identify programmatic activities to minimize this risk, and increase the proportion of projects whose savings are able to be assured through deemed savings, deemed calculators, and Light M&V.

RECOMMENDATIONS

We offer the following recommendations.

➡ **Revise the existing protocols to add detail regarding M&V activities**, such as sampling, calculation of savings, selecting monitoring points, and generally addressing questions that arise when practicing M&V. We recommend that the revised M&V protocols follow the guidance provided by the International Performance Measurement and Verification Protocol (IPMVP), so that BPA's M&V practices are IPMVP-adherent. The recommended revisions include such things as: identifying the IPMVP Option (A, B, C, or D) the engineer should use; requiring documentation of baseline equipment and operational characteristics; and expanding the description of the calculations to be used, including describing the data to be collected and how the data are to be used in the calculations. Revision of the protocols will also enable BPA to specify more robust M&V techniques supported by advanced metering technology that was formerly cost-prohibitive.

➡ **Develop or revise five or six of the following protocols** in the remaining portion of this research contract. (The contract specifies that five or six protocols will be developed or revised.)

- ***End-Use Metering*** – revision of an existing protocol
- ***Energy Use Indexing*** – revision of an existing protocol
- ***Existing Building Commissioning*** – a new protocol
- ***Packaged Commercial HVAC*** – a new protocol
- ***M&V Protocol Selection*** – a new protocol providing guidance on selecting the appropriate M&V protocol for the measure and site
- ***Sampling*** – a new protocol
- ***Regression*** – a new protocol for analyzing time-series data in support of site-specific M&V of a custom project

➡ **Conduct research subsequent to this project** to determine the proportion of projects that received standard M&V in spite of their eligibility for Light M&V, and the variance of post-installation savings estimates from pre-installation estimates by measure type and size category. Based on this investigation, the subsequent research should recommend an appropriate kWh threshold or alternative thresholds corresponding to measure type or other decision criteria for invoking the Light M&V Plan.

➡ **Require M&V engineers to conduct Light M&V for all eligible projects.**

➡ **Bring together the regions' M&V protocols and savings assurance tools (such as sampling instruction formulas, default assumptions, key reference materials, and deemed savings calculators) into a single repository.**

➡ **Improve documentation of M&V activities** (time spent and protocol used by project) **and entries in the Planning, Tracking, and Reporting (PTR) system** (measure type, pre- and post-installation savings estimates, and protocol used) to support M&V activities throughout the region and facilitate risk-reduction analyses**.**

➡ **Take steps to address problems stakeholder contacts indentified in the conduct of M&V.** Consider actions to address the following:

- Align responsibility and authority within BPA for approving M&V plans and the resulting savings estimates.
- Simplify the processes by which utilities upload their efficiency information into BPA's PTR database.
- Bring cost documentation requirements in line with risk, so that requirements focus on higher-cost project elements rather than all cost elements.

➡ **Coordinate the evolution of BPA's M&V policies and procedures with the evolution of its evaluation strategy and activities.** M&V and evaluation should work in tandem to understand the risks attending BPA's efficiency resource acquisitions, and to understand how to address those risks in a cost-effective manner through: IPMVP-adherent M&V protocols; Light M&V; deemed savings estimation calculators; deemed measures; programmatic approaches; and evaluations of programs and measure types. For example, BPA has the opportunity to conduct a meta-evaluation of the M&V analyses of custom projects of a similar type, assessing the findings for variance of post-installation estimates from pre-installation estimates, and for relationships among the drivers of savings and the savings estimates. For project types for which there is small variance and/or the relationships between savings drivers and savings outcomes appear evident, BPA might consider classifying the project type as eligible for Light M&V or developing a deemed savings calculator.

1 INTRODUCTION

The Bonneville Power Administration (BPA) uses Measurement and Verification (M&V) protocols to measure and verify savings for custom energy conservation projects implemented by BPA customer utilities under the Conservation Rate Credit (CRC) and the Energy Conservation Agreement (ECA).[1] Since 1999, BPA has required that energy savings be verified according to M&V protocols that have been developed by BPA staff or the Regional Technical Forum (RTF). These protocols are available on its website. Some BPA customers that have bilateral contracts with BPA have also developed their own M&V protocols that satisfy the criteria of BPA's.

The *Draft Sixth Northwest Power Plan*[2] of the Northwest Power and Conservation Council (NWPCC) forecasts a need for BPA customers to increase their implementation of energy efficiency measures and boost energy savings. Increased energy savings acquisition necessitates an increase in savings assurance activities, including M&V. Therefore, BPA requested that Research Into Action, Inc. – in association with Left Fork Energy, Inc., Warren Energy Engineering, LLC, Quantum Energy Services & Technologies, Inc. (QuEST), and Schiller Consulting, Inc. – review the M&V site-specific protocols in reference to best practices in M&V and to the sectors and activities targeted by BPA's resource acquisition activities, and make recommendations for revising and augmenting the protocols. This report details our findings, conclusions, and recommendations from that review.

In phase two of the research contract, we will revise existing and/or develop new M&V protocols for BPA's consideration.

BPA customer utilities vary widely in their M&V capabilities, in their capacity for energy efficiency, and in their use of energy efficiency as a customer service. Similarly, wide diversity exists among the utilities' contractors and consumers. This diversity poses a challenge to any effort to update the protocols. This project therefore seeks to assist BPA in developing and/or revising protocols consistent with best practices that will support the execution of M&V by utilities with widely varying circumstances and by M&V engineers with widely divergent experience.

The project approach has six steps, as noted below. This report is being finalized after Step 5. The remaining project activities will entail the development and revision of M&V protocols and will not generate a separate research report.

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1 Replaces the Conservation Acquisition Agreement (CAA) governing the prior rate period.

2 Northwest Power and Conservation Council. 2009. *Draft Sixth Northwest Power Plan.* Portland, Ore.: Northwest Power and Conservation Council. *http://www.nwcouncil.org/energy/powerplan/6/DraftSixthPowerPlan_090309.pdf*

1. Research and document BPA's current and historic M&V practices.
2. Review best practice M&V protocols.
3. Identify gaps in BPA's current approaches relative to identified best practices and to BPA's energy efficiency savings acquisition.
4. Present results of the assessment to BPA.
5. Work with BPA to determine protocol revision and development activities for the remainder of the project.
6. Develop and/or revise M&V protocols as determined in Step 5.

The following briefly outlines our methods to date.

➡ **Step 1 – Review BPA's M&V Protocols:** The first step comprised three activities.

- We obtained summary information on BPA's efficiency resource acquisition activities and programs to provide background for this research; we then analyzed project data received from BPA, identifying sector, end-use, measure, and savings for the CRC and CAA custom projects completed during the preceding rate period (see Chapter 2).
- We characterized BPA's M&V protocols with respect to their context (sector and application), and according to key features of the International Performance Measurement and Verification Protocol (IPMVP – see Chapter 2).
- We interviewed staff members of BPA, its customer utilities, and other regional stakeholders to understand their assessment of the M&V protocols (see Chapter 4).

➡ **Step 2 – Review Best Practice M&V Protocols:** Our team reviewed non-BPA M&V protocols for best practices. In Chapter 3 we review:

- IPMVP
- ASHRAE Guideline 14
- M&V Guidelines for Federal Energy Projects
- PJM Manual
- California Standard Performance Contract Program, 2000
- California Commissioning Collaborative's Guidelines
- National Trends

➡ **Step 3 – Identify Gaps Between Best Practice and BPA's M&V Protocols:** Our team identified gaps in BPA's current approaches relative to identified best practices and

BPA's energy efficiency savings acquisition and developed recommendations for protocol revisions and new protocol development (see Chapter 5).

➡ **Step 4 – Present Assessment Results to BPA:** This step comprised the delivery of the draft version of this report and meetings with BPA staff to discuss its implications.

➡ **Step 5 – Work with BPA to determine protocol revisions and development activities for the remainder of the project:** We conducted this activity while preparing the final version of this report. This report reflects the decisions made.

2 BPA'S CUSTOM PROJECTS AND M&V PROTOCOLS

This chapter comprises three sections. The first section describes the programmatic context for BPA's use of M&V to assure the savings of custom energy efficiency projects. The second section presents our analysis of the savings associated with custom projects by project type, based on custom project data BPA provided us from its tracking database. The third section provides a characterization of BPA's M&V protocols.

SUMMARY OF BPA'S CUSTOM PROJECT ACTIVITY

As outlined in Chapter 1, BPA currently reimburses utility customers for savings realized by end-users through the implementation of energy efficiency and other conservation strategies, in accordance with the Energy Conservation Agreement (ECA) or the Conservation Rate Credit (CRC) reimbursement programs. The ECA supersedes the Conservation Acquisition Agreement (CAA), through which BPA reimbursed the utilities for energy efficiency projects conducted during the previous rate period.

For some measures, the savings and reimbursement are deemed; for others, the deemed savings value depends on the measure characteristics and are determined by using BPA's approved deemed savings estimation calculators. BPA defines all measures that do not fit the deemed or deemed savings calculator approach as custom measures.

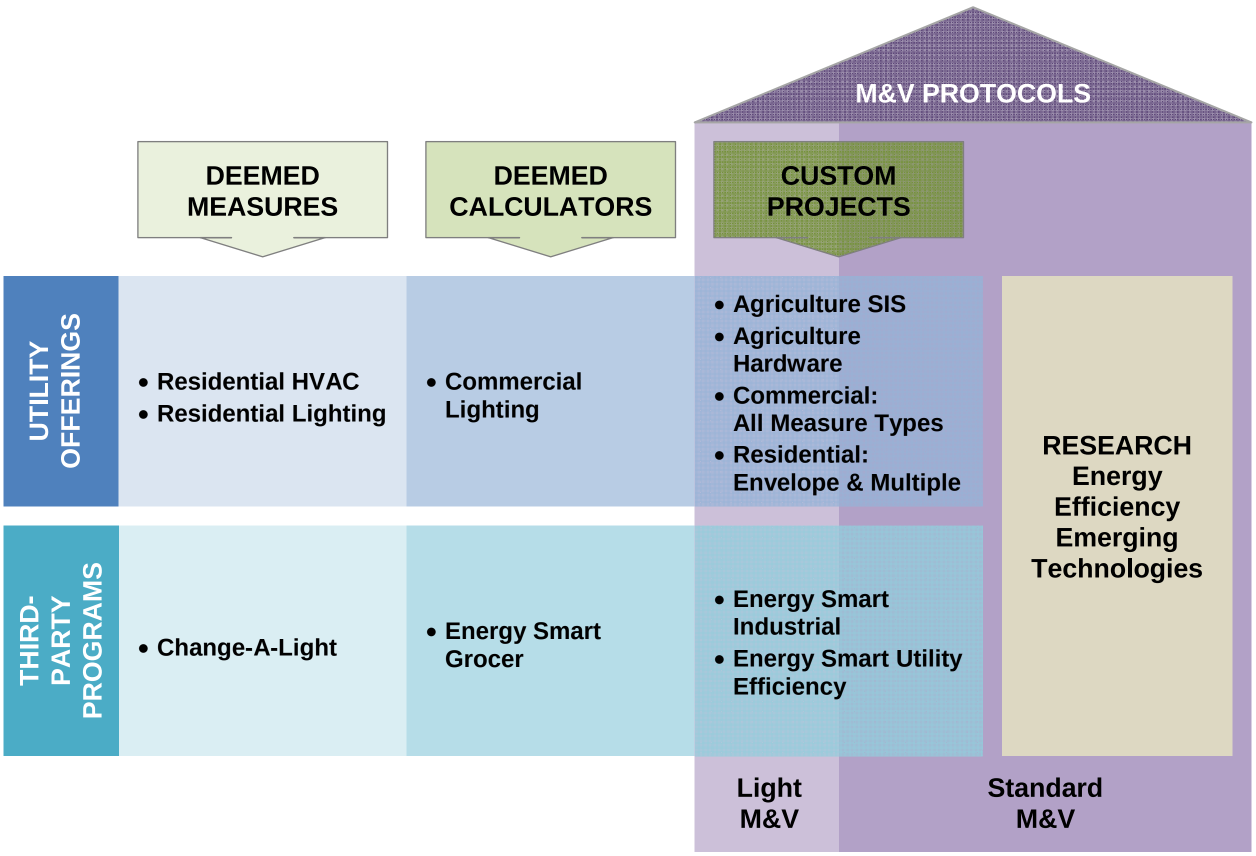
BPA's customer utilities can implement custom projects in any sector, as long as the activities satisfy the requirements of the CRC/ECA. As shown in Table 2.1, to date industrial measures have comprised 59% of all BPA's custom project energy savings, agricultural measures 25%, commercial measures 16%, and residential measures 0.04%. For custom measures, the focus of this research project, BPA requires M&V before reimbursement.

Table 2.1: Summary of Custom Project Savings by Sector

SECTOR	VERIFIED SAVINGS	
	kWh/Year	Percent of Total
Agriculture / Irrigation	53,232,696	25%
Commercial	34,285,056	16%
Industrial	127,211,257	59%
Residential	88,855	<1%
TOTAL	**214,817,864**	**100%**

Figure 2.1 illustrates the role of M&V protocols in assuring energy savings from BPA's efficiency activities. The figure shows two horizontal paths to illustrate the energy efficiency acquired by BPA's customer utilities under the Conservation Rate Credit and Energy Conservation Agreement, and acquired by programs implemented for BPA by third-party implementation contractors. From left to right, the figure illustrates a progression of increasingly resource-intensive savings assurance methods: measures with deemed savings; measures with deemed savings estimation calculators; and all other measures, which BPA classifies as custom projects and assures through M&V conducted in accordance with its site-specific M&V protocols.

Figure 2.1: Programmatic Purview of BPA's M&V Protocols



The region's M&V engineers, many of whom are staff of BPA, can use the Light M&V Plan for projects with expected annual energy savings of less than 200,000 kWh per year. The Light M&V Plan corroborates the measure installation and operation, as well as the engineering calculations underpinning the pre-installation savings estimate, but does not include post-installation monitoring over time or the development of a post-installation savings estimate.[3] For projects larger than the 200,000 kWh threshold, engineers must use the Standard M&V Plan, specifying the appropriate measure- and site-specific protocol. We describe the 11 BPA-approved M&V protocols in this chapter's final subsection.

Among the significant findings of our research are those facets of BPA's M&V activities about which we remain unable to comment. These include the proportion of projects eligible for Light M&V, yet for which the M&V engineer followed a standard M&V protocol, and the proportion of BPA's total custom project savings measured and verified with each protocol. We pursued both of these analyses, but the data provided by BPA were insufficient for us to estimate these proportions.

The *Conservation Rate Credit and Conservation Acquisition Agreement Implementation Manual*, dated April 2009, describes the application process for custom projects. Steps conducted by BPA's utility customers include:

- ➡ Submit a custom project proposal, including M&V plan
- ➡ Secure review and approval of proposal by BPA
- ➡ Submit a project completion report, including M&V findings
- ➡ Secure BPA approval of project completion report

Projects with projected savings of 200,000 kWh/year or more submit a Standard M&V Plan, specifying the appropriate measure- and site-specific protocol as given in the Regional Technical Forum's (RTF) *Appendix P Energy Savings Verification Protocols*, the BPA *Site Specific Verification Guidelines*, and/or American Society of Heating, Refrigeration, and Air-conditioning Engineers' (ASHRAE) *Guideline 14-2002 Measurement of Energy and Demand Savings*. Projects with projected savings less than 200,000 kWh/year may submit a Light M&V plan in which the savings are based on engineering calculations supported by commissioning, inspection, and/or spot measurement data.

Utility Offerings of Custom Projects

Through BPA incentives, Northwest public electric utilities offer services and financial reimbursements for eligible custom energy efficiency measures applicable to any sector. As shown in Table 2.1, above, industrial sector savings comprised 59% of custom savings, agricultural sector savings comprised 25%, commercial 16%, and residential less than 1%.

During the current rate period, BPA will acquire industrial sector savings from the third-party programs described in the next subsection.

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3 Details regarding Light M&V Plan can be found in the CRC/CRA *Implementation Manual* 2009, page 8.

For the prior rate period, Table 2.4 (below, in *Analysis of BPA Custom Project Savings*) provides a break-out of energy savings by measure type. Among savings from agricultural custom measures, Scientific Irrigation Scheduling (SIS, a process growers use to improve irrigation water management) constitutes 65% of savings, motors and drives constitute 18%, and pumps constitute 8%.

Savings from HVAC measures constitute 36% of commercial custom savings, lighting 27%, multiple measures 11%, and motors and drives 9%.

The custom project data we received from BPA indicates four residential projects during the previous rate period.

Third-Party Programs with Custom Projects

The CRC/CAA data from the previous rate period that we analyzed does not include any third-party programs with custom projects, as BPA launched these efforts in late 2009. Going forward, the CRC/ECA custom project data will include that of the Energy Smart Industrial (ESI) Program and the Energy Smart Utility Efficiency Program, both administered by third-party implementation contractors.

The ESI includes the following elements:

- ➡ **An industrial energy efficiency expert** assigned by the ESI program to provide utility efficiency program staff with a single point-of-contact for coordinating ESI programs and resources to meet the goals and needs of their conservation program
- ➡ **An Energy Management pilot** that addresses the opportunities to acquire energy savings through improved operations and maintenance (O&M) and management practices

  This pilot has three subcomponents: co-funding for energy project manager staff; implementation of track and tune projects (O&M or retro-commissioning-like activities with permanent metering and reporting systems in place); and high performance energy management (training and support for incorporating efficiency into a firm's continuous improvement processes).
- ➡ **A Small Industrial component** that provides a cost-effective mechanism to handle specific efficiency measures where the energy savings on individual projects are small relative to typical industrial projects
- ➡ **Enhanced Lighting**, an extension of the existing Northwest Lighting Trade Ally Network, to drive more industrial lighting projects
- ➡ **Expansion and enhancement of traditional technical service proposal (TSP) consultant services**, including quick-response time and materials work, and BPA funding of scoping, measurement, and verification activities where appropriate

The industrial custom project data from previous rate periods provides BPA with the best available proxy of future industrial custom project activity. The CRC/CAA data detailed subsequently in Table 2.4 show industrial custom savings of 26% for motors and drives, 22% for compressed air, 14% for a category our analysis labels *other,* and 10% for lighting.

Energy savings from the third-party BPA Energy Smart Utility Efficiency Program will also be tallied among the CRC/ECA custom industrial project data. This program offers utilities incentives for distribution system efficiency improvements and voltage optimization, historically known as *conservation voltage reduction.* Although distribution efficiency measures are included in BPA's industrial sector, utilities are not required to participate in the Energy Smart Industrial program in order to participate in the utility efficiency offer.

ANALYSIS OF BPA CUSTOM PROJECT SAVINGS

BPA provided our team with a spreadsheet report of custom projects from its Planning, Tracking and Reporting System (PTR) database for the CRC/CAA programs.[4] Table 2.1, above, shows the total savings (kWh/year), as well as savings aggregated by sector; not surprisingly, industrial energy savings dominate, followed by agricultural energy savings.

The table provides a direct summary of BPA's data, with no consideration of M&V type. The data we received from BPA lacked an indicator of the type of M&V conducted for projects. BPA plans to conduct research subsequent to this project to analyze additional PTR data, including (as available) type of M&V conducted, and both pre- and post-M&V savings estimates. Based on this investigation, the subsequent research should be able to recommend an appropriate kWh threshold, threshold by measure type, or other decision criteria for invoking the Light M&V Plan

Table 2.4, below, provides a breakdown of savings by measure type within each sector. However, we first need to present to the reader our methodology for deriving those savings data. Although best practices in data management would have the PTR database constrain the measure list to a set of pre-defined types, the PTR appears to allow the user to enter the measure type unconstrained, resulting in a proliferation of terminology for what is essentially the same measure. Table 2.2 illustrates this proliferation of PTR measure-type terms in the PTR field *Measure Category* we recognize as *adjustable speed drives* (ASDs), based on our record-by-record review of the data in the PTR field *Measure Name.*

4 *CompletionReportMeasures.xls.*

Table 2.2: PTR Terms Used for Measures We Categorized as Adjustable Speed Drives

PTR "MEASURE CATEGORY" TERMS FOUND FOR ADJUSTABLE SPEED DRIVE PROJECTS	
• Adjustable/Variable Motors	• Multiple Measures
• Adjustable Speed Drives	• Other Agricultural Measures
• Centrifugal Pumps	• Other Industrial Measures
• Electrical Equipment	• Plant Process System Efficiency Improvements
• Existing HVAC System Measures	• Process Energy
• Heating & Air Conditioning	• Pumps and Fans
• HVAC	• Pumps & Fans
• HVAC System Measures	• Refrigeration
• Irrigation Hardware	• Refrigeration Systems
• Motors	• Variable Speed Drive on Vacuum Pumps Over 10 HP
• Motors & Drives	• Ventilation Measures

By reviewing in tandem the information in the PTR fields *Measure Category* and *Measure Name*, we consolidated the 53 unique *Measure Category* labels into 17 unique measure categories we term for this report *Measure Category (As Defined by Research Into Action).* Table 2.3 provides the 17 unique Research Into Action Measure Categories.

Table 2.3: Research Into Action Measure Categories

MEASURE CATEGORY (AS DEFINED BY RESEARCH INTO ACTION)	
• Chillers	• Multiple Measures
• Compressed Air	• Refrigeration
• Control of Office Equipment	• Scientific Irrigation Scheduling
• Envelope	• Utility Distribution
• Fans	• Vacuum Pumps
• HVAC	• Water Heating
• Irrigation	• Pumps
• Lighting	• Other
• Motors and Drives	

We attempted to group measures into even broader categories – for example, to determine the end-use for an ASD (HVAC or refrigeration) – but in many cases this was not possible using the available information. In addition, some measure categories could be combined, yet we kept them separate if the measure types were particularly distinct. An example of this is maintaining separate categories for *Chillers* and *HVAC*. *HVAC* typically refers to small equipment or airside measures and *Chillers* obviously refers to large waterside HVAC equipment. We placed measures for which we could not determine a category (and unusual or rare measures) in the *Other* category. This was most common for industrial measures. These constraints and thought processes resulted in the category list shown in Table 2.3.

We also created a slightly more granular breakdown that may be subsequently valuable for specific analyses. For example, we separated the *Motors and Drives* data into two separate categories: *Motors* and *Adjustable Speed Drives*. Ultimately, we did not use this breakdown in the summaries in this report.

Using our *Measure Category (As Defined by Research Into Action)* designation, we summarize in Table 2.4 the custom project energy savings by sector and measure type. To report cost-effectiveness, we added a *Simple Payback Period* field, which we calculated as the *Total Project Costs* divided by the *Verified Savings*, using an assumed price of $0.10/kWh. The lower the simple payback number, the more cost-effective the project.

Average Measure Savings provide an indication of whether significant savings came from a few large projects or many small projects. *Scientific Irrigation Scheduling* dominates the savings for agriculture. In the commercial sector, *HVAC* and *Lighting* were responsible for the majority of savings. No single measure type dominates industrial savings.

Table 2.4: Summary of Custom Project Measure Savings, Count, Cost

MEASURE CATEGORY (As Defined by Research Into Action)	NUMBER OF MEASURE	VERIFIED SAVINGS		AVERAGE MEASURE SAVINGS (KWH/YR)	TOTAL ACTUAL MEASURE COST ($)	SIMPLE PAYBACK PERIOD (Years, assuming $0.10/kWh)
		KWH/YEAR	PERCENT OF TOTAL			
AGRICULTURE / IRRIGATION						
Scientific Irrigation Scheduling (SIS)	8	34,776,450	65%	4,347,056	$1,527,258	0.44
Motors and Drives	57	9,473,361	18%	166,199	$2,944,700	3.11
Pumps	26	4,450,685	8%	171,180	$1,073,113	2.41
Utility Distribution	3	2,891,352	5%	963,784	$128,363	0.44
Other	6	635,971	1%	105,995	$205,428	3.23
Irrigation	8	467,880	1%	58,485	$478,473	10.23
Lighting	3	320,671	1%	106,890	$137,757	4.30
Refrigeration	6	216,326	0.4%	36,054	$221,670	10.25
Total Agriculture / Irrigation	**117**	**53,232,696**	**100%**	**454,980**	**$6,716,763**	**1.26**

Continued

MEASURE CATEGORY (As Defined by Research Into Action)	NUMBER OF MEASURE	VERIFIED SAVINGS		AVERAGE MEASURE SAVINGS (KWH/YR)	TOTAL ACTUAL MEASURE COST ($)	SIMPLE PAYBACK PERIOD (Years, assuming $0.10/kWh)
		KWH/YEAR	PERCENT OF TOTAL			
COMMERCIAL						
HVAC	67	12,322,855	36%	183,923	$7,714,468	6.26
Lighting	107	9,409,164	27%	87,936	$3,553,590	3.78
Multiple Measures	8	3,896,958	11%	487,120	$1,522,013	3.91
Motors and Drives	27	3,090,976	9%	114,481	$1,967,795	6.37
Refrigeration	18	2,161,092	6%	120,061	$1,643,670	7.61
Office Equipment Controls	8	1,346,206	4%	168,276	$234,301	1.74
Fans	3	988,259	3%	329,420	$465,664	4.71
Chillers	5	548,415	2%	109,683	$823,121	15.01
Envelope	11	281,728	1%	25,612	$162,364	5.76
Compressed Air	6	145,564	0.4%	24,261	$58,039	3.99
Other	4	91,552	0.3%	22,888	$55,717	6.09
Water Heating	2	2,287	0.01%	1,144	$567	2.48
Total Commercial	**266**	**34,285,056**	**100%**	**128,891**	**$18,201,309**	**5.31**
INDUSTRIAL						
Motors and Drives	81	33,611,012	26%	414,951	$13,123,106	3.90
Compressed Air	90	27,893,705	22%	309,930	$6,121,304	2.19
Other	26	18,187,961	14%	699,537	$7,751,045	4.26
Lighting	22	13,103,615	10%	595,619	$2,456,502	1.87
Utility Distribution	7	9,026,834	7%	1,289,548	$624,458	0.69
Refrigeration	26	8,824,476	7%	339,403	$6,236,755	7.07
Pumps	11	5,664,179	4%	514,925	$788,485	1.39
Fans	7	4,188,696	3%	598,385	$2,536,573	6.06
Vacuum Pumps	3	2,927,375	2%	975,792	$497,949	1.70
Multiple Measures	1	2,549,163	2%	2,549,163	$1,480,189	5.81
HVAC	8	1,102,077	1%	137,760	$531,805	4.83
Chillers	1	132,164	0.1%	132,164	$78,318	5.93
Total Industrial	**283**	**127,211,257**	**100%**	**449,510**	**$42,226,489**	**3.32**
						Continued

MEASURE CATEGORY (As Defined by Research Into Action)	NUMBER OF MEASURE	VERIFIED SAVINGS		AVERAGE MEASURE SAVINGS (KWH/YR)	TOTAL ACTUAL MEASURE COST ($)	SIMPLE PAYBACK PERIOD (Years, assuming $0.10/kWh)
		KWH/YEAR	PERCENT OF TOTAL			
RESIDENTIAL						
Multiple Measures	2	82,742	93%	41371	$136,926	16.55
Envelope	1	6,113	7%	6,113	$10,000	16.36
Lighting	1	0	0%	0	$68,463	0
Total Residential	**4**	**88,855**	**100%**	**22,214**	**$215,389**	**24.24**
ALL SECTORS						
TOTAL	**670**	**214,817,864**	**NA**	**320,624**	**$67,359,949**	**3.14**

CHARACTERIZATION OF BPA'S M&V PROTOCOLS

The Research Into Action team reviewed the 11 M&V protocols suitable for the M&V of custom projects requiring a Standard M&V Plan. The protocols are published in two documents:

- *Site Specific Verification Guidelines*, BPA, May 1992[5]
- *Energy Savings Verification Protocols*, Regional Technical Forum, September 2000[6]

Table 2.5 provides a quick overview of the 11 M&V protocols; the subsequent tables provide a more detailed summary of each protocol. The last column in the table, *Similarity to IPMVP*, refers to the four International Performance Measurement and Verification Protocol (IPMVP) Options:

- *Option A. Retrofit Isolation: Key Parameter Measurement*
- *Option B. Retrofit Isolation: All Parameter Measurement*
- *Option C. Whole Facility*

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5 Harding, S., F. Gordon, and M. Kennedy. 1992. *Site Specific Verification Guidelines*. Portland, Ore.: Bonneville Power Administration. *http://www.osti.gov/energycitations/servlets/purl/5171979-iBVWcf/5171979.pdf.*

6 Regional Technical Forum. 2000. *The Regional Technical Forum's Recommendations to the Bonneville Power Administration Regarding Conservation and Renewable Resources Eligible for the Conservation and Renewable Resources Rate Discount and Related Matters, Appendix P: Energy Savings Verification Protocols Conservation and Renewable Resources Discount*. Portland, Ore.: Northwest Power & Conservation Council. *http://www.nwcouncil.org/rtf/crd/recommendations/appendices.htm.*

➡ *Option D. Calibrated Simulation*

Table 2.5: Overview of BPA's M&V Protocols for Custom Project Savings Verification

PROTOCOL NAME	APPLICATION	SIMILARITY TO IPMVP
Verification by Billing Analysis	Large buildings	Option C (uses monthly bills)
Verification by Connected Load Measurement	A measure that changes electrical load but not operating hours	Option B
Verification by Equipment or End-Use Metering	A measure that changes both load and operating hours	Option B
Verification by Energy Indexing	Equipment whose energy use is impacted by the measure and also by some driving variable not affected by the measure (example, temperature)	No correspondence
Verification by Hybrid Methods	Multiple measures with interactive effects between measures	No correspondence (generates estimated net savings)
RTF Group No. 1	Residential buildings with energy savings at least 5% of whole house consumption	Option C (utility bill method; recommends a control group to adjust for non-program changes in energy use)
RTF Group No. 2	New residential buildings	Option D (focused on HVAC end-uses; uses a computer simulation of the building)
RTF Group No. 3	Nonresidential buildings with a single measure or multiple measures that are not interactive	No correspondence (project savings based on ex ante engineering estimates, adjusted for weather or other non-program changes; does not directly estimate savings from measurements, yet adjusts savings based on utility meter impacts)
RTF Group No. 4	Nonresidential buildings with interactive measures generating at least 500,000 kWh annual savings	Option D (uses a calibrated model of the building incorporating explicit modeling of the measures)
RTF Site Specific No. 1	Non-interactive, constant load measures	Option A (uses measurements of load and operating hours; allows sampling and basing of savings for un-sampled equipment on engineering estimates, which may not be IPMVP-adherent)
RTF Site Specific No. 2	Nonresidential sites with at least 100,000 kWh savings and/or complex weather-sensitive measures Also new industrial processes using a baseline from a similar process or plant	Option B for first application (nonresidential sites) No correspondence for second application (new industrial processes)

The IPMVP, which we discuss in Chapter 4, is a guidance document that represents a professional consensus on acceptable M&V practices for developing reliable savings estimates for water- and energy efficiency projects. Readers should not construe our use of the term "similarity to IPMVP" to imply IPMVP adherence. We examined the 11 protocols by considering their context (sector and application), their correspondence and adherence to the IPMVP options. Our reviews also evaluated how each protocol addressed the following seven elements commonly included in M&V protocols found in other jurisdictions.

- Sampling
- Site reviews
- Data requirements
- Baseline
- Uncertainty
- Reporting format
- Calculations

Table 2.6 through Table 2.16 summarize our characterization of the BPA M&V protocols relative to sector and application, and their relationship to the IPMVP. We present the findings here without comment; Chapter 5 *Gap Analysis of BPA's M&V Protocols* provides an assessment of the protocols with respect to national best practices. We offer recommendations for augmenting or modifying the protocols in Chapter 6 *Conclusions and Recommendations.*

Table 2.6: Verification by Billing Analysis

SUBJECT	REVIEW FINDING
Reference	*Site Specific Verification Guidelines*. Page 17. BPA. 1992.
Target Sector	Not sector specific.
Application	Large buildings with small variance in annual energy consumption. Applies to all measures where savings are "at least 15-20% on an annual basis."
IPMVP or other	Predates, but is similar to IPMVP Option C. Not as well defined as Option C; bill comparison allowed.
Sampling	Not applicable; assumed to apply to single project.
Baseline	Protocol calls for 1-4 years of baseline energy bills where there is little variation in use year to year. Protocol recommends baseline adjustments for weather-dependent measures, but does not describe how to do this.
Calculations	Only example is a simple bill comparison with no baseline adjustment.
Site Reviews	Not an explicit requirement, though periodic surveys during performance period are recommended to protect against decay in savings.
Data Requirements	1-4 years baseline billing history; billing history for performance period with no recommendation for length of time.
Uncertainty	No discussion about uncertainty.
Report Format	None provided.
Comments	Protocol does not clearly address the need for baseline adjustments to account for weather, occupancy, or construction. Lacks calculation algorithms and guidance on reporting results, including uncertainty. Protocol allows for sampling, but does not specify a method or provide guidance.

Table 2.7: Verification by Connected Load Measurement

SUBJECT	REVIEW FINDING
Reference	*Site Specific Verification Guidelines*. Page 23. BPA. 1992.
Target Sector	Not sector specific.
Application	For measures that reduce connected load, but not operating hours, and that result in small savings relative to building load.
IPMVP or other	Like Option B, but applies only to measures with constant baseline load and no change in operating hours from baseline to post-installation.
Sampling	Sampling is allowed, but little guidance given as to how to ensure that the sample is representative.
Baseline	Baseline kW is measured; baseline hours are assumed equal to post-retrofit hours, which are measured.
Calculations	Delta kW x Hours = delta kWh.
Site Reviews	Periodic surveys are recommended to verify that measures remain in place and operate as intended. Recommends repeated measurements of connected load during performance period to verify persistence.
Data Requirements	Equipment inventory, measurement of connected load.
Uncertainty	No discussion about uncertainty.
Report Format	None provided.
Comments	Protocol does not clearly address the need for baseline adjustments to account for weather, occupancy, or construction. Lacks calculation algorithms and guidance on reporting results, including uncertainty. Protocol allows for sampling, but does not specify a method or provide guidance. No discussion about accounting for interaction between measures. No discussion about regression analysis.

Table 2.8: Verification by Equipment or End-Use Metering

SUBJECT	REVIEW FINDING
Reference	*Site Specific Verification Guidelines*. Page 25. BPA. 1992.
Target Sector	Not sector specific.
Application	For measures that reduce both operating hours and load (e.g., ASDs), but where the savings are too small to be reliably observed in the utility billing record.
IPMVP or other	Like Option B.
Sampling	Not discussed.
Baseline	Baseline kWh is measured for a sufficient period of time to capture weather and occupancy variations, a minimum of 2 months.
Calculations	Baseline kWh – post-retrofit kWh = delta kWh.
Site Reviews	Not required or discussed.
Data Requirements	Baseline and post-installation kWh.
Uncertainty	No discussion about uncertainty.
Report Format	None provided.
Comments	Protocol does not clearly address the need for baseline adjustments to account for weather, occupancy, or construction. Lacks calculation algorithms and guidance on reporting results, including uncertainty. No discussion of accounting for interaction between measures. No discussion of regression analysis.

Table 2.9: Verification by Energy Indexing

SUBJECT	REVIEW FINDING
Reference	*Site Specific Verification Guidelines*. Page 33. BPA. 1992.
Target Sector	Industrial, though it could apply to large commercial spaces with variable occupancy rates.
Application	All measures where energy use changes due to non-program effects, e.g. production rates in an industrial plant.
IPMVP or other	Not an IPMVP method, but is similar to the IPMVP procedure for routine and non-routine adjustments.
Sampling	Not discussed.
Baseline	Baseline energy is measured and then calculated on a per-unit basis. Measurement period is at least two months and must capture seasonal variations. Baseline also may include a capped production rate so that BPA does not pay for increased production made possible by the energy savings.
Calculations	(Baseline kWh – post-retrofit kWh) / Baseline kWh. This percent is multiplied by the baseline energy consumption for the savings.
Site Reviews	Not required or discussed.
Data Requirements	Baseline and post-installation kWh and production rates.
Uncertainty	No discussion about uncertainty.
Report Format	None provided.
Comments	Protocol does not clearly address the need for baseline adjustments due to weather, construction, or other non-production variables. Lacks calculation algorithms and guidance on reporting results, including uncertainty. No discussion of accounting for interaction between measures. No discussion of regression analysis. Assumes a linear relationship between production and energy consumption.

Table 2.10: Verification by Hybrid Methods

SUBJECT	REVIEW FINDING
Reference	*Site Specific Verification Guidelines*. Page 37. BPA. 1992.
Target Sector	Not sector specific.
Application	A facility with multiple measures using different measure-specific measurements. Addresses double counting and interactive effects.
IPMVP or other	Not an IPMVP method, but like IPMVP, addresses double counting and interactive effects.
Sampling	Not discussed; probably not applicable.
Baseline	Baseline energy is determined by one of the earlier methods.
Calculations	None given.
Site Reviews	Not required or discussed.
Data Requirements	Determined by one of the earlier methods.
Uncertainty	No discussion of uncertainty.
Report Format	None provided.
Comments	Appears to be an after-calculation adjustment to earlier methods, though this is not clear.

Table 2.11: RTF Group No. 1

SUBJECT	REVIEW FINDING
Reference	*Appendix P, RTF Energy Savings Verification Protocols, Conservation and Renewable Resources Discount, Group Protocols No. 1.*
Target Sector	Existing Residential.
Application	Residential measures where billing data are available and program savings are at least 5% of baseline consumption.
IPMVP or other	Addresses billing analysis like Option C, but uses different techniques.
Sampling	Sampling is allowed for both participants and nonparticipants.
Baseline	Protocol calls for at least one year of baseline energy bills. Protocol requires normalizing to weather (either dry bulb temperature or heating degree days with a custom balance point). A control group is required to account for non-program effects.
Calculations	Savings for individual participants are calculated as the difference between weather normalized pre- and post-installation annual energy use. Program savings subtract the savings from participants from those of nonparticipants. The protocol recommends use of PRISM for the calculations.
Site Reviews	Not specified.
Data Requirements	At least one year of pre-installation and one year of post-installation billing history.
Uncertainty	90% confidence interval is required for sample sizes, but precision is not specified.
Report Format	None provided.
Comments	Sampling as described in this protocol would apply to an impact evaluation, not a project-specific M&V determination of savings. Lacks instructions on how to normalize energy use. No specification for sampling precision.

Table 2.12: RTF Group No. 2

SUBJECT	REVIEW FINDING
Reference	*Appendix P, RTF Energy Savings Verification Protocols, Conservation and Renewable Resources Discount, Group Protocols No. 2.*
Target Sector	Residential New Construction (single-family, manufactured, and low-rise multifamily).
Application	Measures that affect heating, ventilation, or cooling end-uses, such as envelope improvements, duct sealing, or high efficiency HVAC equipment.
IPMVP or other	Similar application as the IPMVP New Construction protocol in Volume 3 of the IPMVP, but less rigorous.
Sampling	Allowable for calculating program savings. Sampling is not applicable for determining savings at a particular site.
Baseline	The baseline is a simulation model produced by removing measures influenced by the program from the as-built simulation model. The baseline shall not be less efficient than current energy code, but may be more efficient. A control group should be used where there is no building code.
Calculations	Savings for an individual building are the difference between simulated energy use of the baseline and as-built models.
Site Reviews	Field verification is required. It must verify: 1) the energy-efficient features influenced by the program; and 2) general characteristics of the building required to create a simulation model.
Data Requirements	None, though documentation documents (such as pre-program designs) are required in order to count specific measures.
Uncertainty	90% confidence interval is required if sampling is used. Stratification between sectors is recommended. Precision is not specified.
Report Format	None provided.
Comments	The documentation said to be required of baseline design may be hard to obtain. Typical weather is used in the simulations and no calibration is required if one of six pre-approved software programs is used. Specifying 90% confidence for sampling is meaningless without also specifying precision. Field verification includes determination of program influence, though this is normally the purview of the impact evaluator.

Table 2.13: RTF Group No. 3

SUBJECT	REVIEW FINDING
Reference	*Appendix P, RTF Energy Savings Verification Protocols, Conservation and Renewable Resources Discount, Group Protocols No. 3.*
Target Sector	Existing Commercial and Industrial.
Application	Small nonresidential buildings or larger buildings with non-interactive measures.
IPMVP or other	No direct IPMVP equivalent.
Sampling	Permitted for determining program savings.
Baseline	The baseline can be obtained through either regression or use of a control group. An ANOVA process is required as the regression technique to estimate the influence of the ex-ante savings, independent variables such as weather, and original engineering variables.
Calculations	Savings for individual participants are calculated as the difference between weather (or other independent variable) normalized pre- and post-installation annual energy use. A realization rate is calculated by comparing this estimate of savings to predicted savings. The program savings are obtained by applying the realization rate to the population of participants.
Site Reviews	Not specified, but site characteristics must be obtained by some method.
Data Requirements	At least one year of pre-installation and one year of post-installation billing history. Independent variables such as operating hours and occupied floor space must be collected for the same period.
Uncertainty	Not specified.
Report Format	Not specified.
Comments	This is an impact evaluation protocol, not a project- or measure-specific M&V protocol. Applies to groups of projects.

Table 2.14: RTF Group No. 4

SUBJECT	REVIEW FINDING
Reference	*Appendix P, RTF Energy Savings Verification Protocols, Conservation and Renewable Resources Discount, Group Protocols No. 4.*
Target Sector	C&I measures with large impacts.
Application	C&I new construction, interactive measures, or complex weather-sensitive measures. Projects with at least 500,000 kWh savings.
IPMVP or other	Similar to the IPMVP New Construction protocol in Volume 3 of the IPMVP.
Sampling	Not recommended because the individual projects are large. It is acceptable if the evaluation cost would be >10% of program cost.
Baseline	The baseline is a simulation model produced by removing measures influenced by the program from the as-built simulation model. The baseline shall not be less efficient than current energy Code but may be more efficient. A control group should be used where there is no building code.
Calculations	Savings for an individual building are the difference between simulated energy use of the baseline and as-built models. The as-built model should be run with actual post-installation weather data for calibration, but the model should be run again with typical weather to obtain savings.
Site Reviews	Field verification is required. It must verify: 1) the energy-efficient features influenced by the program; and 2) general characteristics of the building required to create a simulation model.
Data Requirements	At least one year of post-installation billing records. Onsite verification of as-built physical and operating characteristics. Verification of those measures influenced by the program.
Uncertainty	The model should be calibrated to within 10% of annual energy use and 25% of any month's energy use.
Report Format	None specified.
Comments	DOE-2.1E is the recommended tool.

Table 2.15: RTF Site Specific No. 1

SUBJECT	REVIEW FINDING
Reference	*Appendix P, RTF Energy Savings Verification Protocols, Conservation and Renewable Resources Discount, Site Specific Protocol No. 1.*
Target Sector	Nonresidential (primarily industrial).
Application	Industrial Motors, Lighting (not weather-sensitive, multiple measures/site).
IPMVP or other	Essentially Option A, though IPMVP is not referenced.
Sampling	Sampling is recommended within a site where measures were applied to multiple systems. Measures should be stratified by common end-use, schedules, demand, or other shared characteristics.
Baseline	The baseline is not described by the protocol. It would presumably be characterized by the engineering calculations using baseline characteristics for the affected systems.
Calculations	Savings calculations are performed with simple engineering calculations informed by spot or short-term monitoring of key performance parameters (e.g., hours of operation, installed kW).
Site Reviews	Required for field verification of installed measures, as is spot or short-term monitoring of key performance parameters.
Data Requirements	Spot or short-term monitoring data.
Uncertainty	Not specified.
Report Format	Not specified.
Comments	The protocol is similar to IPMVP Option A, but with less specificity. Stratification and sampling procedures are not described.

Table 2.16: Site Specific No. 2

SUBJECT	REVIEW FINDING
Reference	*Appendix P, RTF Energy Savings Verification Protocols, Conservation and Renewable Resources Discount, Site Specific Protocol No. 2.*
Target Sector	Primarily large industrial, and also large single end-use.
Application	C&I measures with large savings and/or complex weather-sensitive measures. Projects with at least 100,000 kWh savings.
IPMVP or other	Essentially Option B, though IPMVP is not referenced.
Sampling	Not allowed.
Baseline	For new construction or new process, the baseline is the normalized baseline energy use obtained from a similar process in the facility or from a different plant. For retrofits, baseline monitoring is required.
Calculations	For a new process, the savings is the difference between the per-unit of production energy intensity for the baseline and new cases, times actual production. Unit production is based on monitoring. For retrofit applications, the savings is the difference between monitored baseline and post-retrofit operations.
Site Reviews	Spot or short-term monitoring of key performance parameters is required, but on-site measure verification is not required.
Data Requirements	The energy use of the affected systems should be directly measured, in addition to all significant parameters affecting energy use. The duration of onsite energy monitoring is to be long enough to capture the full range of operating conditions. Pre-installation and post-installation metering are required.
Uncertainty	Not specified.
Report Format	Not specified.
Comments	The protocol is similar to IPMVP Option B but is less detailed. The requirement that baseline metering be performed can be difficult to achieve.

3 NATIONAL M&V PRACTICE

This chapter reviews M&V protocols developed by industry, nonprofit, governmental, and other organizations to establish procedures and methods to quantify savings from energy conservation projects and programs in a transparent and repeatable fashion. These documents form the basis for M&V as practiced in the United States for the calculation of savings due to energy-saving and demand-response projects.

The section begins with a discussion of two protocols: the *International Performance Measurement and Verification Protocol* (IPMVP)[7] and the American Society of Heating, Refrigeration, and Air-conditioning Engineers' (ASHRAE) *Guideline 14-2002 Measurement of Energy and Demand Savings*. IPMVP and ASHRAE Guideline 14 help define what constitutes the acceptable conduct of M&V.

Following the discussion of IPMVP and ASHRAE publications are examples of M&V guidelines developed for specific energy efficiency programs; these publications put into action the principles described in the fundamental documents.

The remainder of this chapter reviews examples of the application of deemed savings and stipulated values, describes the use of deemed savings calculators by energy-saving programs, discusses the relationship between M&V and impact evaluation, and concludes with a brief survey of emerging trends in the practice of M&V.

FUNDAMENTAL PROTOCOLS

The international practice of M&V is founded on a remarkably small number of documents. Of primary significance is the *International Performance Measurement and Verification Protocol*. The IPMVP is a guidance document because, rather than prescribing how to perform M&V, it delineates the components and activities that constitute an acceptable degree of measurement and verification in proportion to the level of risk and uncertainty for the savings expected from a water- or energy efficiency project. Most major energy efficiency programs in the United States reference the IPMVP in their M&V procedures.

Closely tracking and providing support to the IPMVP is ASHRAE Guideline 14-2002. ASHRAE Guideline 14 complements the IPMVP by delving deep into the topics of uncertainty, regression analysis, and instrumentation, and by providing working examples of M&V for specific applications.

7 *IPMVP Volume 1, Concepts and Options for Determining Energy and Water Savings*, is developed by and available from the Efficiency Valuation Organization (EVO): *www.evo-world.org*.

While a few other references, such as the *Federal Energy Management Program (FEMP) Guidelines* and the *California Evaluation Protocols* (both reviewed later in this section), often are cited in connection with the framework of M&V, nearly all refer back to the IPMVP and ASHRAE Guideline 14.

International Performance Measurement and Verification Protocol

The IPMVP is a guidance document that defines common terminology, identifies documentation requirements and reporting periods, and describes high-level practices in quantifying savings based on energy measurements and analysis. It presents a framework of four M&V Options that allow broad flexibility in applying the fundamental M&V concepts to calculate and report a project's savings.

The IPMVP has been used extensively by energy service companies, the federal government, and several states to establish the basis of performance payments, determine carbon and NO_x reductions, and to quantify savings in utility program evaluations. Originally called the *North American Energy Measurement and Verification Protocol* (NEMVP) when it was first published in 1996, it was renamed IPMVP when revised in 1997. Revisions of the IPMVP are targeted every five years, with the most recent revision published in 2007.

The IPMVP is intended for use by industry professionals to increase transparency and reliability of reported savings. Because the IPMVP is not a standard, each user must establish their own specific M&V Plan (according to recommendations in the IPMVP), which addresses each project's unique characteristics. While there is no formal compliance mechanism, adherence with the IPMVP may be claimed if the projects include development and implementation of an M&V Plan that is:

- Consistent with IPMVP terminology
- Identifies and uses an IPMVP Option
- Describes specific measurement, monitoring, and analysis methodologies
- Identifies baseline and reporting period timeframes
- Describes quality assurance procedures
- Identifies the roles and responsibilities of the involved parties

The IPMVP's fundamental concept stems from the fact that energy savings cannot be directly measured. Savings are the absence of the energy use that would have occurred without the energy conservation measure (ECM), project, or program. Savings are determined by comparing energy use before and after project implementation, and after making appropriate adjustments to make the comparison under the same set of conditions. Figure 4.1 demonstrates this fundamental concept.

Figure 4.1: Conceptual Demonstration of IPMVP Savings Determination

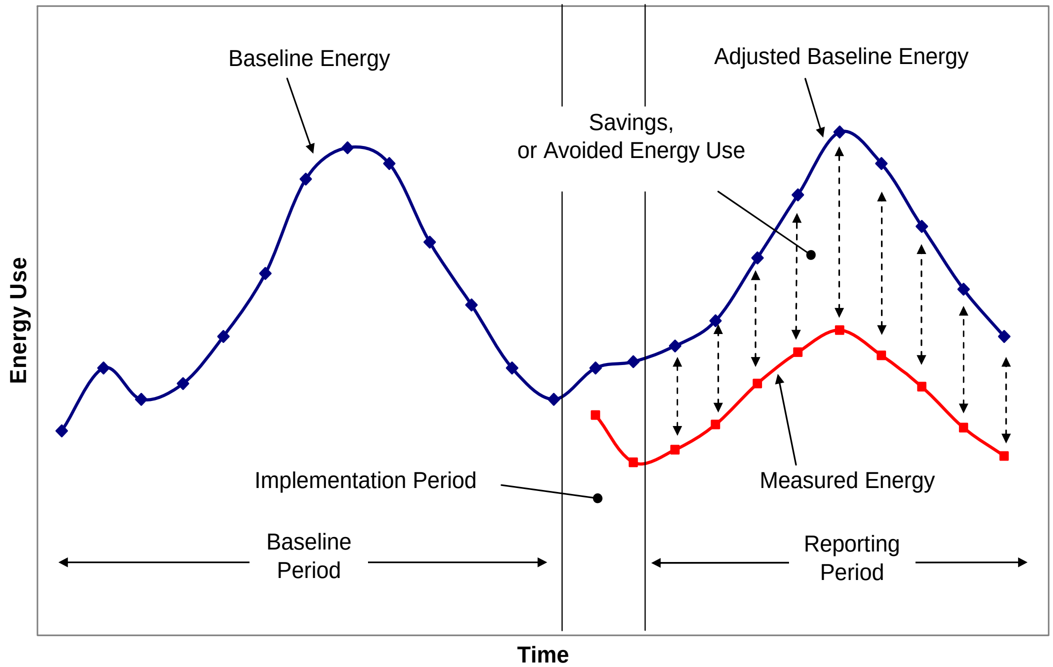

Figure 4.1 shows that an IPMVP-adherent process is based on energy measurements. In Figure 4.1, only the *Baseline Energy* and the reporting period's *Energy Use* can be measured. The *Adjusted Baseline Energy* must be determined from appropriate adjustments to the baseline energy use. Adjustments are *routine or predictable variations* in energy use, such as changes in a building's load throughout a day, or *non-routine*, such as when equipment is shut down for unexpectedly long maintenance periods. The IPMVP requires that all planned adjustments be documented in the M&V Plan. A project's savings are determined from the difference between the adjusted baseline energy and the reporting period's measured energy use.[8]

An important distinguishing feature of IPMVP-adherent M&V is that savings are determined and reported well after the ECM or project has been installed, as compared to engineering calculations, which are determined prior to project implementation. Another distinguishing feature is that the IPMVP methods provide the means to determine the project's savings uncertainty.

When there is little doubt that a project realizes energy savings, M&V may not be necessary. However, it is still wise to verify through inspection or functional testing that the installed ECM

8 Note that the IPMVP also allows savings to be determined by adjusting post-installation energy use to the baseline conditions.

or project has the potential to generate savings; but such verification is not IPMVP-adherent, as no energy measurements are made.

The IPMVP provides four Options that allow users to select the best approach, according to their project's cost and savings requirements, and particular technology or energy program. Table 4.1 summarizes the IPMVP Options.

Table 4.1: IPMVP Options

IPMVP OPTION	HOW SAVINGS ARE CALCULATED	TYPICAL APPLICATIONS
A. Retrofit Isolation: Key Parameter Measurement Savings are determined by field measurement of the key performance parameter(s) that define the energy use of the ECM's affected system(s). Parameters not selected for measurement are estimated, and must be based on historical data, manufacturer's specifications, or engineering judgment.	Engineering calculation of baseline and reporting period energy from: • Short-term or continuous measurements of key operating parameter(s); and • Estimated values.	A chiller upgrade where the chiller kW/ton is the measured key performance parameter. Cooling loads served by the chiller are estimated based on agreed-upon load conditions.
B. Retrofit Isolation: All Parameter Measurement Savings are determined by field measurement of the energy use of the ECM-affected system.	Short-term or continuous measurements of baseline and reporting-period energy, and/or engineering computations using measurements of proxies of energy use.	Replacement of inlet guide vanes (IGV) on a fan motor with a variable-speed drive. Monitor and record every 5 minutes the IGV-fan motor electric power and the duct static pressure for all anticipated operating conditions in the baseline period. Record the ASD-fan motor electric power and duct static pressure throughout the reporting period to track variations in power use.
C. Whole Facility Savings are determined by measuring energy use at the whole-building level, typically using records provided from the local utility.	Analysis of whole-building baseline energy use using simple comparison or regression with continuously monitored independent parameters. Continuous measurements of the entire building's energy use are taken throughout the reporting period.	An energy management program affecting many systems in a building. Monitor energy use with the gas and electric utility meters for a 12-month baseline period and throughout the reporting period.
		Continued

IPMVP OPTION	HOW SAVINGS ARE CALCULATED	TYPICAL APPLICATIONS
D. Calibrated Simulation Savings are determined through simulation of the energy use of the whole building. Simulation routines are calibrated so that they adequately model actual energy performance measured in the facility. This Option usually requires considerable skill in calibrated simulation.	Energy use simulation, calibrated with hourly or monthly utility billing data. Energy end-use metering may be necessary to help refine input data.	An energy management program affecting many systems in a building. Situations where no meter existed in the baseline period. Baseline energy use, determined using the calibrated simulation, is compared to a simulation of reporting period energy use.

ASHRAE Guideline 14: Measurement of Energy and Demand Savings

ASHRAE Guideline 14 is a formal application of IPMVP's principles. Its intent is to provide detailed technical guidance on using measurements to quantify energy savings. Similar to the IPMVP, ASHRAE Guideline 14 requires post-retrofit energy use to be measured and compared with pre-retrofit energy use, with adjustments or normalization, to determine savings. Use of ASHRAE Guideline 14's methods should produce results that are reasonably accurate and provide confidence to parties of an energy-conservation project that there is a sound basis for payments.

ASHRAE Guideline 14 describes four *paths* to compliance. Compliance is achieved when savings can be stated with uncertainty less than or equal to 50% at the 68% confidence level. Three compliance paths require estimations of savings uncertainty, while the fourth path, which is a prescriptive path, does not. Guideline 14 describes three specific approaches and provides a compliance path for each:

1. Whole-building metering
2. Retrofit isolation metering
3. Whole-building calibrated simulation

These approaches are very similar to IPMVP Options B, C, and D.

Guideline 14 provides direction on selecting a performance path and describes in detail each approach. It provides numerous equations, mathematical and statistical definitions, and requirements for each path. Several examples are included. Its annexes provide informative discussions on measurement instruments, their accuracy, savings uncertainty analysis, regression techniques, and additional retrofit isolation techniques.

EXAMPLE M&V GUIDELINES

M&V Guidelines: Measurement and Verification for Federal Energy Projects, Version 3.0

The *M&V Guidelines: Measurement and Verification for Federal Energy Projects* was developed and is maintained by the Federal Energy Management Program in support of federal energy savings performance contracts. The publication is commonly referred to as the *FEMP M&V Guidelines*. The purpose of the Guidelines is to provide:

> "…guidelines and methods for measuring and verifying energy, water, and cost savings associated with federal energy savings performance contracts."[9]

More than any other publication, the FEMP M&V Guidelines bridges the gap between the protocols set forth in the IPMVP and the practical application of those protocols in reporting savings that result from energy- and water-efficiency projects. The document puts meat on the bones of the IPMVP in providing very specific procedures and templates that result in M&V reports that adhere to the IPMVP. Highlights of the FEMP M&V Guidelines that are relevant and useful for updating BPA's M&V protocols are:

- ➡ Selecting an M&V approach
- ➡ Preparing an M&V plan
- ➡ Fully developed M&V plans for lighting equipment retrofits and chiller replacement projects
- ➡ Guidance on M&V for eight specific technologies (lighting, motors, etc.)
- ➡ Templates for M&V plans and reports
- ➡ Graphical decision trees for verifying savings
- ➡ Delineation of the roles and responsibilities for parties to an energy savings project

The FEMP M&V Guidelines is probably the most complete example of an application of the IPMVP framework to a specific program. In this case, it is the Super Energy Savings Performance Contracts managed by FEMP, as legislated by the National Energy Policy Act of 1978, and amended and modified in later years by additional legislation, including the Energy Policy Act of 1992. Though written specifically for this program, the content is applicable to most energy efficiency projects. Indeed, sections of this public-domain document have been incorporated into guidance manuals for a number of rate-payer-funded energy efficiency programs, including the New York State Energy Research and Development Authority (NYSERDA) Commercial/Industrial Performance Program and the Oncor (formerly TXU Electric) Large Commercial and Industrial Standard Offer Program. In

9 FEMP Guidelines, Version 3.0. p. 1-1

these programs and others, customers and participants are required to conduct M&V according to the guidelines.

PJM Manual 18B: Energy Efficiency Measurement and Verification

PJM Interconnection is one of several regional transmission organizations (RTO) that coordinates movement (buying, selling, and delivery) of wholesale electricity. PJM serves all or parts of 13 states and the District of Columbia. It permits energy efficiency resources to participate in its Energy Market and, theoretically, energy efficiency "negawatts" can compete on an equal footing with generation megawatts. In order to receive capacity payments from PJM, energy efficiency resource providers must comply with the M&V standards in *PJM Manual 18B*.[10]

Manual 18B lists all four IPMVP Options as acceptable measurement and verification methodologies. It also permits *Engineering Calculations and Audit Results* and *Load Shape Analysis* as acceptable alternative methodologies. The inclusion of these alternatives appears to be a concession to the requirements of program impact evaluations.

Much of the language in Manual 18B is written as if it was setting standards for project-level M&V, rather than for program-level impact evaluation (see the section *M&V, Impact Evaluation, and Verification*, below). It is our understanding that the main energy efficiency service providers bidding energy efficiency resources in the market are expected to be electric utilities or non-utility energy efficiency program administrators. Thus, the energy efficiency resources primarily are programs rather than projects. In this respect, the language of the Manual is somewhat inconsistent with its application, and with the language of the general M&V and program evaluation communities.

In drafting Manual 18B, PJM drew heavily from the *ISO New England Manual for Measurement and Verification of Demand Reduction Value from Demand Resources*.

California Standard Performance Contract Program, 2000

California launched the Nonresidential Standard Performance Contract program in 1998. The program was intended to deliver substantial energy savings while also helping to transform the market for energy efficiency services. It offered higher incentive levels ($/kWh) than the custom incentive programs it replaced, but placed a substantial M&V burden on the applicant. Customers received incentive payments based on M&V conducted at the customer's cost for two

10 *PJM Manual 18B, Revision 0*, with an effective date of April 23, 2009, was reviewed for this report. PJM Forward Market Operations. 2009. *PJM Manual 18B: Energy Efficiency Measurement and Verification, Revision 0*. Norristown, Penn.: PJM Interconnection. *http://www.pjm.com/~/media/documents/manuals/m18b.ashx.*

years following installation of the project. Here we review *Section III*, *Measurement and Verification Guidelines*, of the Year 2000 version of the program manual.

The manual references the four IPMVP options, but does not allow Option A. However, this appears to be an earlier incarnation of Option A, described as "stipulated savings." The current IPMVP Option A requires some measurement and is not stipulated savings. The manual provides guidelines on selecting the proper M&V Option for different measure types (Table 4.2).

Table 4.2: Guidelines for Selecting M&V Options

MEASURE TYPES	OPTIONS
Lighting Efficiency and Controls	Monitoring Operating Hours
Constant Load Motor Efficiency	Short-Term and Continuous Metering
ASD	1 – Constant Baseline 2 – Variable Baseline – Performance Curves with Metering 3 – Variable Baseline – Correlating Power to Independent Variable Values
Chiller Replacement	1 – Metering Chiller kW 2 – Metering Chiller kW and Cooling Load
Generic Variable Load	Continuous Post-installation Metering
Other Option	Billing Analysis Using Regression
Other Option	Calibrated Computer Simulation Analysis

Over the years, California gradually loosened the M&V requirements; program savings estimates have become more prescriptive. California developed standardized calculation templates that calculated stipulated savings for common measures.

California Commissioning Collaborative Guidelines

The California Commissioning Collaborative published *Guidelines for Verifying Existing Building Commissioning Project Savings: Using Interval Data Energy Models, IPMVP Options B and C*. Users refer to this document by the shorter name of *EBCx-M&V Guideline*.

EBCx-M&V describes how to apply IPMVP M&V concepts and ASHRAE methodologies to existing building commissioning (EBCx) projects. It is designed to help commissioning service providers, building owners and managers, and energy efficiency program managers to understand how to manage, design, and complete robust M&V procedures within individual EBCx projects. It provides guidance on designing M&V strategies, identifying and using data resources, selecting an energy modeling methodology, scheduling M&V activities within the the process of an EBCx project, and leveraging the many synergies between the IPMVP and ASHRAE processes.

The EBCx-M&V Guideline describes two M&V approaches – system isolation (Option B) and whole-building (Option C with short-time interval data, e.g. 15-minutes) – and one fundamental methodology – inverse energy modeling based on statistical regressions and change-point models. Its focus is on the energy performance of the building and its subsystems, and therefore the quantification of the cumulative savings of all operational improvements within these boundaries. The guideline describes how the improvements from an EBCx process can be sustained through ongoing energy modeling and performance monitoring. The California Commissioning Collaborative (CCC) recognizes that there are other verification methods that may better meet different project and program goals. Under a Public Interest Energy Research grant from the California Energy Commission, the CCC has begun developing additional verification of savings guidelines and methods. Both IPMVP-adherent and non-adherent methods will be documented in the new guidelines.

DEEMED SAVINGS AND DEEMED SAVINGS CALCULATORS

Deemed savings, deemed savings calculators, and technical resource manuals provide standardized algorithms for calculating estimated savings from energy efficiency measures, plus suggested or stipulated values for the input variables (hours of operation, load factor, etc.) included in the algorithms. The use of deemed savings values or deemed savings calculators does not constitute M&V as defined by the IPMVP. However, these two approaches do provide savings estimates for each measure, based on expected average installation conditions in a program's operating territory. Deemed savings values by definition are not adjusted for actual operating conditions, provided they conform to the general assumptions specified for the input variables.

Deemed savings calculators can inform the M&V process by providing:

- **Estimates of probable measure savings** – a necessary input in balancing cost and risk when preparing an M&V plan
- **Algorithms to be included in an M&V plan for calculating baseline and post-retrofit energy use and demand** – in an IPMVP-adherent M&V process, the input variables to the algorithms would be either partially (Option A) or entirely (Option B) measured

Conservation Resource Comments Database

The *Conservation Resource Comments Database*,[11] a product of the Northwest Regional Technical Forum (RTF), is a collection of 59 *Excel* workbooks that creates narrowly defined measures, provides stipulated savings values, and calculates incentive levels. According to BPA staff, the database is a collection of the cost-effectiveness runs that the RTF does for every

[11] Available from: *http://www.nwcouncil.org/rtf/reports.htm*.

measure. BPA uses these spreadsheets to upload data into the PTR and set reimbursement levels. The database currently covers all *Fifth Plan* measures.

The database does not include a user's manual and, since each workbook is very complex (involving a dozen or more worksheets, plus links to other workbooks), it is not clear how the database is used, or can be used, by program implementers. Nonetheless, the load shapes, economic data, and weather files are local to the BPA service territory and the database provides a valuable resource to BPA's customers; in our opinion, it could be made even more useful were it to include a user's manual and simplified inputs sheets.

Technical Reference Manual (TRM) No. 2009-54

The *Technical Reference Manual* (TRM) is a product of Efficiency Vermont, Vermont's statewide provider of energy efficiency services. The TRM:

> "…provides methods, formulas and default assumptions for estimating energy and peak impacts from measures and projects promoted by Efficiency Vermont's energy efficiency programs."

The TRM describes approximately 190 measures with associated deemed savings values. The TRM is updated annually and the research behind the assumptions and deemed values usually is documented. It uses a standard format in which each measure is described, using the same computational path and standard tables for input variables. The TRM does not report cost savings or benefit/cost ratios.

The TRM also stipulates free-ridership and spillover factors to be used in calculating net-to-gross ratios and a measure persistence factor. Attribution (the degree of a program's influence in causing the installation of a measure, as captured by a net-to-gross ratio) rightfully belongs to the evaluation discipline; the IPMVP is silent on the issue of attribution. The calculation of a net-to-gross ratio generally has been reserved for the evaluation process and is calculated at the program level; whereas, M&V is concerned with energy and demand (and water) savings at the project level.

Database for Energy Efficient Resources (DEER)

Database for Energy Efficient Resources (DEER) database,[12] developed under the California Public Utilities Commission, is a voluminous online document designed to support the evaluation of California rate-payer-funded programs. The DEER contains highly detailed stipulated values for the California market, including data for 16 weather zones, 8,760-hour load shapes, and net-to-gross ratios and effective useful life values that are revised periodically. Energy performance data are derived from past evaluations and computer simulations. Like the

12 See: *www.deeresources.com*.

TRM, the DEER database is useful as a support tool for M&V, but savings values obtained from DEER are not IPMVP-adherent.

M&V, IMPACT EVALUATION, AND VERIFICATION

M&V, impact evaluation, and verification are closely related activities that have distinct applications and goals that set them apart from one another. Users frequently fail to see the boundaries that separate these because they confuse the purposes of each. Following is a brief discussion of their relationships and distinctions.

M&V is the process of using energy-use measurements and performance indicators to report reliable savings estimates from individual sites or projects.

Impact evaluations[13] determine the net savings (and possibly additional co-benefits) that result from the operation of an energy-saving program. Since a program's savings is the summation of the savings from the collection of projects caused by the program, M&V is usually an integral part of an impact evaluation.[14] The converse is not true, however, since impact evaluations, in order to report a program's net effect, adjust M&V savings to account for actions that would have occurred, even in the absence of the program (free-riders), and sometimes account for additional savings that occurred as a result of, but were not reported by, the program (spillover.) An impact evaluation can require independent M&V for a sample of completed projects, or can use the results of M&V activities that were conducted in connection with a project's implementation. In either case, the M&V is a stand-alone process that produces information – individual project savings – used in the evaluation; the M&V process does not constitute impact evaluation.

Verification is the process of confirming that the measures associated with a project are installed, installed correctly, operating correctly, and have the potential to generate the savings predicted for the project. Verification confirms a potential to save, whereas M&V uses measurement data in addition to calculate and report savings for actual performance. Impact evaluations can and do use the verification approach in reported program savings, often in conjunction with the use of deemed savings values.

The following formal definitions summarize the distinguishing features and some characteristics of the three terms discussed above.

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13 Other evaluation types include process and market effects evaluations. Collectively these are referred to as *evaluation, measurement, and verification*, or *EM&V*. The term *EM&V* is often applied loosely to refer to one or more evaluation activities.

14 Impact evaluations can also use other approaches besides M&V, including using deemed savings for installed measures, and conducting a comparative billing analysis of a census of program participants and a sample of similar nonparticipant facilities.

- **M&V** – a process with two components: verification of the potential to generate savings; and verification of savings, based on analysis of energy and related (performance indicators) measurements to reliably report savings from individual sites or projects. M&V is conducted at the project level, consistent with the guidelines outlined in the IPMVP. A process that does not adhere to the IPMVP is not considered M&V.
- **Impact Evaluation** – the activities undertaken to determine the net effect of an energy-saving program. Impact evaluations use M&V, verification, market research, and large-scale data analysis of billing records, or various combinations of these approaches, in making a determination.
- **Verification** – the process of confirming measures are installed, operational, and have the potential to achieve the predicted savings. Verification does not use analysis of energy and related measurements to report savings and therefore does not conform to the IPMVP. Verification typically relies on engineering calculations, deemed savings values, stipulated operating parameters, or a combination of these to report measure and project savings.

Additional information regarding the relationships between M&V, evaluation, and verification can be found in several contemporary publications, two of which were reviewed for this report and informed the preceding discussion. These publications should be considered secondary or supporting references for the BPA M&V protocol update study, as their focus is on program evaluation, not on M&V.

The first, the *Model Energy Efficiency Program Impact Evaluation Guide*,[15] a product of the National Action Plan for Energy Efficiency, provides a framework to the planners and administrators of energy-saving programs to help plan and administer an impact evaluation. The publication summarizes the tools and processes that are used in quantifying the net savings impacts that result from program operations. Besides being a basic primer, the publication includes sections on identifying evaluation goals and calculating gross and net benefits, and relates evaluation activities to the operations of energy-saving programs. There is also a chapter on quantifying avoided air emissions (with a focus on CO_2) that result from a reduction in energy use due to the programs.

The second, *The 2006 California Energy Efficiency Evaluation Protocols,*[16] prepared for the California Public Utilities Commission, is a set of official protocols used to guide evaluation

[15] National Action Plan for Energy Efficiency Leadership Group. *Model Energy Efficiency Program Evaluation Guide*. 2007. U.S. Environmental Protection Agency. 2007. Washington, D.C.: U.S. Environmental Protection Agency. *http://www.epa.gov/cleanenergy/documents/evaluation_guide.pdf*.

[16] *TecMarket Works Team. 2006. California Energy Efficiency Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals. San Francisco, Calif.: California Public Utilities Commission. http://www.calmac.org/events/EvaluatorsProtocols_Final_AdoptedviaRuling_06-19-2006.pdf*.

efforts in California. The Protocols are both more comprehensive than the *Model Energy Efficiency Program Impact Evaluation Guide* (for instance, they include sections on process and market effects evaluations) and more prescriptive (because they are written as a practitioner's guideline for the California energy-saving programs). Evaluations required by the Commission must follow the requirements outlined in the publication. The document is organized into eight protocols, each concerned with a particular aspect of evaluation. Relevant to the BPA M&V protocol update project, is the Measurement and Verification Protocol, which stipulates many aspects of the conduct of M&V that must be followed in order to receive approval from the Commission. The protocols are grounded in the *California Evaluation Framework of 2004*;[17] additional details and tools needed to carry out the protocols can be found in this underlying document.

NATIONAL TRENDS

North American Energy Standards Board

The North American Energy Standards Board (NAESB) has begun a process that may lead to the development of M&V standards that would apply to both wholesale and retail energy efficiency markets. NAESB has recently completed work on M&V standards for demand response products. NAESB is now turning their attention to energy efficiency. In this context, *wholesale* refers to those entities that are directly regulated by the Federal Energy Regulatory Commission (FERC). FERC regulates the transmission and wholesale sales of electricity in interstate commerce. *Retail* markets are regulated by state public utility commissions.

At this point, only two of the regional transmission organizations and independent system operators that are regulated by FERC include energy efficiency directly in their wholesale markets: PJM and ISO New England (ISO-NE). However, FERC Chairman Wellinghoff, speaking at the International Energy Program Evaluation Conference in August 2009, suggested that more entities would be encouraged to include energy efficiency.

NAESB wholesale recommendations could be adopted by FERC and would affect the ability of energy efficiency to be a participating resource in the PJM and ISO-NE areas, as well as in other jurisdictions that may be considering allowing energy efficiency into their capacity markets. It is also possible that FERC could be given responsibility for a national energy efficiency resource standard (EERS), in which case a FERC-endorsed standard could become the basis for enforcing the EERS.

NAESB retail standards are referred to the National Association of Regulatory Utility Commissioners (NARUC) and could be adopted by state public utility commissions as program

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17 TecMarket Works Framework Team. 2004. *California Evaluation Framework*. San Francisco, Calif.: California Public Utilities Commission.. *http://www.calmac.org/publications/California_Evaluation_Framework_June_2004.pdf*.

impact evaluation protocols. It was a request by a state public utility commissioner for guidance on *retail* program evaluation that provided NAESB with the justification to pursue energy efficiency standards.

Evaluation, Measurement and Verification Forum

The Evaluation, Measurement, and Verification Forum (EM&V Forum)[18] is a multi-year project to support the development and use of consistent protocols for the conduct of EM&V, and in the reporting of savings impacts and costs for energy efficiency and demand-side resources. The project developed from a 2006 Northeast Energy Efficiency Partnerships (NEEP) study that found that variations in M&V protocols in the Northeast, and in the reporting of energy efficiency savings, constituted a barrier to regional planning because evaluation findings from different states or jurisdictions were not directly comparable. The study found the Northwest Regional Technical Forum (RTF) to be a model for developing common regional M&V protocols. The EM&V Forum is facilitated by NEEP, and is supported by a consortium of public utility commissions, investor owned utilities, federal and state agencies, trade groups, and not-for-profit organizations.

The Forum is executing a three-year plan (2009-2011) to promote standardized EM&V. To date, the Forum has produced a glossary of terms and acronyms and a catalogue of available end-use and efficiency measure load data. NEEP and the Forum also were contributors to the M&V guidelines prepared for the PJM energy efficiency resources market PJM Manual 18B, reviewed earlier in this report.

The EM&V Forum is representative of a national trend to promote common protocols and assumptions in the calculation and reporting of energy efficiency and demand-response resources. Indeed, one of the Forum's goals – "inform the likely development of national standards and protocols for demand-side resources" – anticipates that the need for standardization is likely to increase in future years.

Increased Availability of Time-Stamped and End-Use Data

A key challenge to implementing IPMVP-adherent M&V for energy- and demand-saving projects is the cost and difficulty of obtaining measured data. While the costliness of data collection is well understood, the difficulty of obtaining the data can be less obvious.

Project developers and utility staff are understandably reluctant to delay the completion of a project so that baseline metering can be planned, installed, and downloaded prior to installation of the energy-saving measures. Where M&V is the responsibility of program evaluators, the energy project typically already has been installed, so no direct metering of the pre-installation

18 See: *http://neep.org/emv-forum*.

conditions is possible. M&V professionals frequently must rely on assumptions when there is a lack of baseline data, thus increasing the uncertainty in the resulting savings estimates. Another common outcome when measured data are difficult or expensive to obtain is that the analyst adopts a verification-only approach in place of true M&V. The greater the uncertainty in project-level savings estimates, the greater the number of projects that must be analyzed in order to maintain a desired confidence in the portfolio-level savings.

These barriers, while still significant, appear to be diminishing as technology (particularly the installation of computerized energy management systems) has increased the amount of building and equipment operating data available to the M&V professional. The ability of these systems to record and store large amounts of trend data is improving. At the same time, at the utility meter level, interval data (typically on a 15-minute basis) increasingly are available through electric distribution company metering systems or from third-party providers of energy information. This trend is likely to accelerate as a result of the national push for “smart meters.”

Widespread availability of interval data will allow the use of sophisticated M&V strategies for large numbers of projects at low cost. Savings estimates for many projects may attain sufficient certainty using interval meter data, making sub-metering of systems or end-uses unnecessary. Currently, most M&V that relies on the use of billing data makes use of monthly meter data. This limits the precision of the method and typically requires that a full year of pre-installation and post-installation data be obtained. More frequent monitoring of energy and the variables that drive its use enables a more complete understanding of this relationship in much shorter time frames than one year. Interval data at the system level, and in some cases at the building level, opens the potential to perform analysis of some measures with only a few weeks of data.

Interval data commonly is analyzed using regression techniques and most projects require only a few independent variables to adequately characterize the energy use. Energy use is likely to be dependent upon categorical variables (such as day-type and occupancy), as well as continuous variables (such as ambient temperature). Common independent variables for the energy use in buildings are:

- Ambient dry bulb temperature (or degree-hours in a change-point model)
- Day of the week
- Occupancy, or hour of the day

Regression techniques also can be used for industrial applications, where the dominant independent variables include production variables and may not include weather or occupancy. Examples include:

- Number of units produced
- Number of gallons processed per hour (or day)
- Units per production shift

The time-stamped and end-use data increasingly available have the potential to reduce costs, reduce the time frame of the M&V analysis, reduce the bias in savings estimates, and increase the confidence and precision of the estimates. The use of such data thus can greatly facilitate the M&V of equipment-based measures. In addition, they can support the M&V of behavioral efficiency measures that previously was not possible due to lack of data granularity or small effect sizes.

BPA has an opportunity to include in revised M&V protocols more robust M&V techniques supported by these advances in metering technology, which were formerly cost-prohibitive.

4 STAKEHOLDERS' ASSESSMENT OF BPA'S M&V ACTIVITY

In this chapter, we present an assessment of BPA's M&V practices according to interviewed staff and contractors of BPA, its customer utilities, and the Northwest Planning and Conservation Council, as shown in Table 5.1. Appendix C identifies our interview contacts and provides our interview guides. The interviews explored: BPA's overall approach to M&V; the use and adequacy of established M&V protocols; areas needing savings assurance; desired confidence in and precision of energy savings estimates; and issues related to the conduct of M&V.

Table 5.1: Completed Interviews

RESPONDENT TYPE	NUMBER OF RESPONDENTS
BPA Staff and Contractors	15
BPA Customer Utility Staff	8
Northwest Planning and Conservation Council Staff	2
TOTAL	**25**

Based on our interviews with utility staff, we characterize the utilities into three tiers in terms of their staffing levels and expertise in the use of M&V protocols.

- ➡ **BPA's largest utility customers** primarily make up the first tier. Over the years, these utilities have established their competence to create and execute their own credible M&V plans. They conduct M&V for their efficiency programs under nonstandard bilateral agreements with BPA, with minimal oversight from BPA.
- ➡ **Utilities with standard agreements that have some staff expertise, yet not sufficient expert resources to conduct all of the M&V work for custom projects** comprise the second tier. These utilities rely on BPA engineers to do much of the M&V work for them.
- ➡ **The smallest utilities** primarily comprise the third tier. These utilities have neither the staff nor the expertise to conduct M&V for custom projects. BPA engineers provide all M&V work for projects implemented by these utilities.

SUCCESS OF SITE-SPECIFIC PROTOCOLS IN ASSURING ENERGY SAVINGS

While we anticipated there would be varied views across types of utilities regarding the protocols, regardless of the size or capability of utility staff, we found that respondents have confidence in the current site-specific M&V protocols and perceive them to be working well.

Utility contacts offered many expressions of the ways in which the protocols are working well for them. Responses included:

- *"Documentation levels required by BPA are working, and the Light M&V Plan is giving us accurate savings."*
- *"I am not aware of gaps in the protocols. M&V now seems appropriate."*
- *"I am satisfied with current protocols and with the way we apply them."*

A fourth utility contact described the interaction with BPA in the following positive terms:

- *"It's worked well to be able to hash things out over time to match the thoroughness [rigor] with the size of project. Flexibility is key: less is better. It is better to acquire savings with uncertainty than not to get savings at all."*

One BPA program staff member offered a similar perspective, saying:

- *"Lots of folks in the region are doing M&V correctly. I don't see lots of opportunity for radical improvement for most of the protocols."*

Protocols as Guidance

In the course of describing their approaches to M&V protocols, utility contacts and BPA staff commonly expressed another idea. Specifically, both groups see the existing protocols as a context for their M&V work, rather than as specific, immutable requirements. For example, a utility contact who reportedly determines what the M&V requirements are for his utility's projects described the protocols as being "like the driving manual." He elaborated, "I'm a good driver with no tickets, but I don't know exactly what's in the manual." Another contact said of his utility:

- *"We do not have all of our protocols clearly defined and identified in writing…. We are close to IPMVP, but not to the letter…. When we look at ASHRAE, BPA, the Regional Technical Forum, IPMVP, NYSERDA, and California, we are consistent with those protocols for custom projects."*[19]

Finally, a third utility contact described his approach as follows:

- *"I read the protocols a few years ago. Since then, I don't go back and refer to them. I take a close look at the industrial process and get what we need to measure. I also talk with BPA."*

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19 ASHRAE is the American Society of Heating, Refrigeration and Air-Conditioning Engineers. NYSERDA is the New York State Energy Research and Development Authority.

A BPA engineer concurred with this opinion:

- *"Most people just ignore the protocols and use their own engineering best judgment. Since there isn't a protocol for every measure, you're making your best guess anyway. I would like to see basic principles and guidelines developed, and make sure everyone knows they are just guidelines, rather than strict protocols. I just use common sense."*

Other BPA engineers confirmed this approach, saying:

- *"I'm not concerned with individual protocols."*
- *"The engineers have to follow the implementation manual. There is not much detail there, just general points. The staff are mostly just expected to do good engineering and use their best judgment."*

Requested Protocol Update

BPA engineering staff would like the BPA 1992 *Site Specific Verification Guidelines*, also known as *The Blue Book*, updated with addition of the latest sub-metering approaches.

ISSUES RELATING TO THE CONDUCT OF M&V

Staff Time and Expertise Required with Site-Specific M&V

One contact described BPA's current approach as leading to the following problem:

- *"The M&V has been excellent, but it has been done by BPA engineers, and there haven't been enough of them to do all of the work."*

Staff resources are also a concern for utility contacts, especially those from smaller utilities. One utility contact reported increasing efficiency acquisition to meet the goals of the *Sixth Plan* will require more staff "because we are already as lean as we can be." Another such contact expressed this concern more dramatically, saying:

- *"We are scared. It's going to be difficult to meet the doubled and tripled targets in the next two years."*

In addition to accelerated resource acquisition, contacts anticipate that engineers skilled in M&V will be retiring during the period covered by the *Sixth Plan*.

- *"The expertise of the engineers we have here is the strongest thing – their years of experience, the people that have been doing this for a long time."*

The concern relates to the transfer of institutional knowledge, in the apparent absence of ways for younger staff to learn from the accumulated experience of their older colleagues. In addition to a general depth of experience, some BPA engineers have reportedly developed specific experience-based protocols and tools that have not been promulgated to a wider audience.

As goals increase, staff will increase; however, at the same time, some BPA staff are retiring. Thus a concern was raised by several contacts that some of the information BPA staff, particularly engineers, currently have is available only to those "in the know." A great deal of knowledge exists that is currently "only in the engineers' heads," and is not readily available for collaborative use or improvement. Contacts indicated tools are needed to bring new members of an expanding workforce up to date quickly and efficiently. One newer BPA staff member indicated a need for a resource that explains "how to do X – for example, a *before–and-after* evaluation – and provides a common-sense explanation of what to do."

Responsibility and Authority

Some contacts – both BPA and non-BPA – commented on BPA's organizational approach to the issue of energy savings verification. Contacts within BPA commented on a lack of integration of M&V and programmatic efforts, the latter including program evaluation. Utility contacts spoke about the chains of responsibility and authority.

For example, one utility contact said:

- *"The BPA engineers who do the M&V do not have the authority to accept the M&V. This is done in a back office by people who don't have the skills to do the M&V. The engineers should have the authority to certify the M&V. This would streamline and make things more efficient. How many handoffs are needed for a BPA M&V report?"*

In this vein, another utility contact reported:

- *"There are sometimes problems with large custom projects. The problem is in dealing with multiple departments within BPA, resulting in misunderstandings."*

Specifically, the contact described different departments within BPA giving different deadlines for the completion of certain tasks, with an impossibly near deadline being given by one department after assurances of adequate time had been made by different BPA staff. That contact stated:

- *"That is not acceptable practice in business. When conflicts come up, deal with them in a rational manner."*

Tracking M&V Activity

Contacts identified a lack of procedures for tracking M&V activity, including tracking: the progression of the M&V activities; the meters installed; the functionality of installed meters; the staff time involved; and the total M&V cost (time and materials) per project. Without these data, it will be difficult to assess the cost-effectiveness of various M&V requirements, an especially sensitive issue for smaller projects.

Documentation

Utility contacts identified several concerns they had with M&V documentation. One utility contact requested simplified cost documentation requirements, saying:

- *"BPA engineers have been good about it, but auditors within BPA are pickier. Some folks at BPA insist on invoices for every nut and screw, which becomes onerous for the end-user participant. It's more of a problem than the energy savings verification."*

Several contacts described the difficulty of putting utility data into the format required by BPA's cost-effectiveness screens, including "onerous" requirements to fit projects into one of three different time bins and to identify incremental costs by measure. Another contact expressed dismay with the complexity offered by the "thousands of possible combinations" for lighting rebates. That contact suggested the program should include the option of a per-fixture rebate.

Barriers to Participation

A utility contact reported BPA's requirement of withholding project payment until M&V is completed is a barrier to participation in incentive programs. That contact suggested the alternative of partial payment of the incentive on project completion, with the balance paid upon verification.

Free-Ridership

Although included in the list of issues for this update to address, free-riders are not considered a concern for any of the contacts outside of BPA. The utilities are "not particularly concerned about free-riders, because it's very hard to suggest in this day and age that no one has heard of or considered doing energy efficiency projects." Two other utility contacts mentioned the difficulty in identifying free-riders, with one of them saying:

- *"It's no longer the case that we're first telling our customers about efficiency and rebates….Utility incentives are part of customers' awareness and decision-making. So it's hard to control for."*

Even a BPA contact expressed ambivalence about BPA's free-ridership guideline that excludes from incentive eligibility all equipment purchased before BPA approves a project. That contact said, "This approach doesn't fit with business cycles. Customers need to spend their budgets and replace their equipment when they need to." The contact continued with the thought that customers with more than one facility could reasonably assume they would be eligible for incentives for subsequent installations, at other facilities, of measures that previously received incentives. The contact related a specific incident in which a customer received the necessary pre-approval at an initial facility, went on to install the same measure in subsequent facilities, and sought an incentive after the fact.

Efficiency Resource Acquisition Tracking Data

While the interviewed contacts did not comment on BPA's tracking data, our evaluation team gained familiarity with it in conducting the analyses presented in Chapter 2. As we stated in that chapter, the highly nonstandard terminology and lack of descriptors of measure applications necessitated our making a number of judgment calls to develop a simple typology of measure types for which we could construct a characterization in terms of number of projects and project savings. And such a characterization is essential in order to understand the comparative risk posed by different measures and applications.

ACCEPTABLE RISK

Many contacts were unable to articulate desirable precision levels for savings estimates. Among those that could, some contacts appeared to use the concepts of confidence and precision loosely.[20]

Contacts (including both BPA and non-BPA sources) that identified acceptable confidence and precision levels, typically suggested that program-wide savings estimates with an 80% likelihood of being within 20% of the true – yet unknowable – value constitute acceptable (but formally undefined by the organization) confidence and precision levels.

At the project – rather than program – level, about half of the engineers, interviewed as a group, agreed that they would "like to see evaluation results and the *ex ante* tool rationalized and get the difference within the 10% to 20 % accuracy requirements." A BPA contact reported, "Plus or minus 20% to 40% on smaller HVAC projects doesn't matter [because the project is small]," while a utility contact thought that plus or minus 50% is acceptable at the project level.

One utility contact commented on actual practice, saying:

- *"Some engineers go 95/5 [confidence/precision], and some try to get 100%, but they end up settling for what they can get."*

This comment suggests, as did comments by other contacts, that some BPA staff seek to avoid risk at all costs and do this through M&V.

NWPCC contacts offered context for their assessment:

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20 *Precision* is associated with a savings estimate, as in the phrase "savings are estimated to be 50,000 kWh, plus or minus 10%." Savings estimates determined from a sample, rather than a population, also have *confidence levels*, as in "the sample size provides an estimate of savings for which there is a 90% likelihood that the estimate is within plus or minus 10% of the true [unknown] value." An estimate of project savings obtained from site-specific M&V has an *associated precision*; because the project is the population and no sampling has occurred, the concept of confidence does not apply.

- *"We think efficiency is a resource costing $30 an average megawatt. If that's about right, then 80/20 confidence precision is fine. A wind project is $100 an average megawatt; for a wind farm, 80/20 is not okay – 80/10 is better than 90/20; 70/10 is probably acceptable; 80/50 – well, that's not good enough. A realization rate [verified savings as proportion of expected savings] of 50% doubles the price of efficiency, and that poses a problem."*

Both BPA engineers and other contacts noted that while BPA's M&V efforts reduce the risk associated with the first-year acquisition of energy savings, they do not address the longer persistence of savings.

MEASURES AND APPLICATIONS NEEDING SAVINGS ASSURANCE

One-third of the savings in the *Sixth Plan* are from measures with which BPA has not traditionally been involved, such as emerging technologies. Emergent technologies have no existing baselines, no protocols, and require extensive data collection to establish savings.

New construction similarly has no baseline data for the newly constructed facility. Contacts would like additional direction from BPA. Contacts seem to be unfamiliar with existing resources and efforts currently underway to address new construction. Regarding existing resources, Volume III of the IPMVP provides guidance for new construction applications, including baseline definitions. Nonetheless, one contact said:

- *"New construction really needs to be settled. IPMVP doesn't make it clear how many months of occupancy you need to get a good reading. "*

Regarding current efforts, an effort termed COMNET (Commercial Energy Services Network)[21] is underway to develop modeling accreditation standards for commercial new construction in a manner similar to those developed for residential new construction under RESNET®. Yet according to one contact:

- *"New construction will be in limbo ten to twenty years from now. Lots of people have tried to get their foot in that door, but it has never worked."*

Contacts also discussed the inclusion in the *Sixth Plan* of industrial behavioral-based measures, for which BPA has no guidelines. Yet as our research team understands BPA's offerings, currently only the Energy Smart Industrial program includes a behavioral component. Respondents knowledgeable about the industrial program believe significant work is necessary to establish M&V protocols for this component.

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21 A joint project of the New Buildings Institute, the Residential Energy Services Network (RESNET®), the Institute for Market Transformation (IMT), and Architectural Energy Corporation (AEC).

The BPA and utility contacts identified other sectors or technologies that need methods of savings assurance, including commercial HVAC (packaged units), building tune-ups, and retro-commissioning. Contacts recommended BPA address efficiency measures for small and medium-size commercial (especially "big-box"-type stores owned by firms with headquarters out of the region) and retrocommissioning of large commercial facilities, which contacts characterize as capable of producing significant savings cheaply. One contact suggested, "Protocols for performance-tested comfort systems, lighting, and ASDs need attention regarding verification of savings rather than measurement."[22] For grocery store refrigeration, savings assurance is needed for floating-head pressure control and other complex control problems. Contacts also requested that BPA designate additional prescriptive measures for commercial lighting and for some types of new construction, especially fast food restaurants.

Note that, as suggested by several of the comments, these perceived gaps in the region's current ability to assure energy savings might be remedied by approaches other than the development of additional site-specific protocols, as we discuss in the next two sections.

NEED FOR SITE-SPECIFIC PROTOCOLS

Contacts described BPA's approach to assuring energy savings, including: the Standard M&V Plans and associated M&V protocols; the Light M&V Plan; deemed savings calculators; and deemed savings. Savings calculators are spreadsheet tools in which the user enters a few parameters that characterize the specific application. Logic within the spreadsheet then generates an application-specific savings estimate for the measure. Contacts mentioned savings calculators were available for lighting, small compressors, dairy pumps, climate controls for potato and onion sheds, some measures installed in grocery stores, and ASDs. Contacts reported some engineers who have extensive experience with specific technologies or applications may have developed additional calculators. For example, an engineer has proposed to the RTF a calculator for variable speed drives in irrigation pumps.

Contacts also suggested neither the Light M&V Plan nor the deemed savings calculators were used at every opportunity, with the result that some measures eligible for a simpler treatment nonetheless are assessed with Standard M&V Plans. For example, some contacts noted the ASD tool is not widely used and other contacts specifically requested that BPA develop an ASD tool, such as that developed by Energy Trust of Oregon. According to one contact, Energy Trust bases incentive payments for ASDs on horsepower, "without a lot of data-logging requirements."

While contacts recognized BPA has adopted strategies (deemed savings, a few sector-targeted programs, savings calculators, and the Light M&V Plan) to reduce the proportion of projects needing the Standard M&V Plan, most contacts expressed the opinion that BPA should take additional steps to further reduce the proportion.

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22 Note that the contact may not be aware of BPA's calculator for adjustable speed drives.

One BPA contact reported, "Relative to other utilities, BPA is M&V heavy." That contact went on to say:

- *"Currently, all projects have either deemed measures or are custom projects, which funnels a lot of projects through the custom approach. I wonder if it might be good to have a middle ground, a simplified calculation tool for small custom projects. What level of M&V is cost effective and what is not cost effective?"*

A utility contact had witnessed the downside that can occur when M&V requirements are perceived as "overly heavy." Referring to industrial compressed air projects, the contact reported:

- *"Sometimes there are vendors who don't want to participate because the M&V requirements are too onerous. These vendors tell their customers not to contact [our utility] because it's too much trouble."*

A contact for one of the utilities with a bilateral agreement also cautioned against a proliferation of protocols. That contact, facing a prospect of separate protocols established by his utility, BPA, and the state in which the utility is located, said it would be undesirable to have multiple sets of protocols with which the utility must comply.

ALTERNATIVE APPROACHES TO ASSURING ENERGY SAVINGS

All contacts are concerned with the ability of the region to assure energy savings from the greatly accelerated resource acquisition as envisioned by the *Sixth Plan*. Both BPA and utility contacts characterize the staffing currently available for M&V as at least somewhat insufficient – resulting in longer timeframes for conducting M&V than would be the case with additional staff. Looking forward, contacts believe the staffing resources to be far short of that necessitated by greatly accelerated resource acquisition in the absence of changes made in M&V.

As stated, most contacts believe the current M&V approach conducts the Standard M&V on too high a proportion of projects. Consistent with strategies BPA already uses to some degree, contacts identified three alternatives with the potential to assure savings at less cost to the region than the current approach, which relies so heavily on site-specific M&V:

➡ Offer additional programs that target specific sectors and measures

➡ Develop additional savings calculators

➡ Conduct program evaluation, relying on a sample rather than a census of projects

Programmatic Approaches to Assuring Energy Savings

Contacts described BPA's Energy Smart Grocer program and its new Energy Smart Industrial program as examples of program designs that assure quality without such a high M&V burden on BPA engineers and utility staff. These programs have turnkey program implementation contractors who use an agreed upon approach to select measures. The Energy Smart Grocer program uses deemed estimates, provisionally deemed estimates, and a savings calculator – all approved by the RTF. The program is also evaluated for program-level savings. For the Energy Smart Industrial program, M&V is now being done primarily by the implementation contractor and technical service providers – an activity that formerly fell to BPA and utility staff. There is no standardized M&V approach that reduces the M&V; instead, the responsibility for most of the M&V has shifted. (BPA will still M&V very large projects, will assure quality of the program, and will evaluate savings at the program level.)

A utility contact said, "The Smart Grocer program has worked extremely well for us," while a BPA engineer elaborated, "There is no M&V component to the grocery program," since the savings are pre-approved in the program agreement. The Energy Smart Industrial program is using a third-party engineering firm for project development and M&V.

Because of these experiences, many contacts believe one effective response to the need to assure savings may be for BPA to use programs to move projects out of the custom-project channel and into standardized approaches that third-parties or the utilities can deliver. This would allow limited M&V engineering resources to focus on the larger and more complex projects.

In particular, contacts suggested a programmatic approach for small commercial applications, a sector contacts consistently characterized as underserved. For new construction, a utility contact suggested creation of a region-wide established prescriptive path for different varieties of new buildings (for example, fast-food restaurants).

Savings Calculators to Assure Savings

Contacts consistently expressed a desire for more savings calculation tools to simplify and accelerate the process of project approval, and anticipated expanded resource acquisition would necessitate new savings calculators. Contacts believe a middle ground is lacking in the current segmentation into deemed and custom measures. Savings calculators would reduce the number of projects classified as custom and thus needing M&V, whether the Standard Plan or the Light Plan. Contacts believe more tools and fewer custom projects would allow a more efficient overall process and still provide sufficient assurance of savings.

Contacts indicated the most effective tools are simple and require no specialized training. They reported tools for commercial projects are a priority and indicated there are few to none currently available. Many contacts identified a need for a savings calculator or calculators for rooftop HVAC units, which were described as "extremely time-consuming" to M&V. A utility contact reported his utility is already working with BPA to develop an approach for commercial HVAC that would employ a spreadsheet for simple savings calculations.

Other contacts requested savings calculators be developed for motors, blowers, fans and pumps, air compressors, controls, and commissioning. As noted previously, some contacts requested a tool for variable frequency drives, while others mentioned the existing ASD tool is not well known. Data centers (considered to be industrial projects by BPA) are also awaiting a tool, which one contact reported is in the early stages of development.

A utility contact suggested BPA might in its current programs allow for a hybrid of deemed and measured-and-verified savings:

- *"I would love deemed numbers and to have the option to use deemed savings or to do a project as a custom project at our discretion. I think it would work for BPA to offer two incentive levels, with a lower one for the faster deemed approach, and let utilities choose."*

Impact Evaluation to Assure Savings

According to some contacts, impact evaluation complements the alternatives of targeted programs and the use of savings calculators as a means of reducing the number of projects for which M&V is required. Some contacts suggested evaluation might be employed across projects throughout the region with the same or related measures, even in the absence of targeted programs.

Evaluation would serve two purposes. For projects not subject to M&V, it would assure savings at the program or regional level. For projects subject to M&V, it would address persistence of savings. In the words of one contact:

- *"If we did evaluations, we could trade off some of the M&V. The evaluation process gives you a feedback loop for your M&V."*

Assuring Savings Through a Research Agenda

Contacts described an institutionalized aversion to risk at BPA that hampers the acquisition of savings. Comments included:

- *"BPA won't start a program without a firm deemed number."*
- *"BPA is in a hard position, as it has needed RTF approval to move forward, but that's too slow."*

Contacts generally agree with the view one person expressed:

- *"The ability to take on a bit of risk, rather than wait until there is absolute certainty, would expedite program launches and savings."*

Certainly, BPA's newly launched Energy Smart Industrial program represents a departure from this stance; to the extent to which contacts mentioned this effort, they approved of BPA's approach.

Several contacts expressed the view that it is better for the region to acquire savings with uncertainty than not to get savings at all. A NWPCC contact expressed this:

- *"At $30 an average megawatt, efficiency is one-third the cost of other resources, so we don't want to slow this down."*

In the view of the NWPCC contacts, the region can afford to take risk in acquiring energy efficiency. When expected savings do not materialize, two outcomes follow: one, the average cost increases for the savings actually acquired; and two, the total efficiency resource reaped by the region falls short of the goal. Given the low comparative cost of efficiency, the first negative outcome should not be considered a deal-breaker; the average cost of actually-acquired efficiency could be considerably higher than forecasted and still be less expensive than supply-side resources.

Regarding the second potential negative risk outcome – that of a regional shortfall in acquired efficiency resources – contacts recommended BPA scale its efforts to reduce risk in proportion to the magnitude of the resources at stake. Some contacts also mentioned BPA should address risk in relation to the rate period during which efficiency funding is fixed. These contacts recommend BPA accept more risk in the early years of the period and, if warranted by mid-period evaluation findings that acquired resources are considerably less than expected, adopt a more risk-averse stance in the latter years of the period.

Although, in the view of many contacts, additional savings calculators provide a means for risk reduction, several BPA engineers noted that the process of creating a new tool can be an obstacle. They described the need in instances of multiple installations of a measure with known characteristics that drive the measure's energy use: up to 18 months of metered data per installation; analysis to understand the relationship between the savings and the application characteristics; and analysis to specify incentives associated with the savings.

Some contacts described ways in which BPA could prudently move forward, yet without attempting to reduce virtually all risk through M&V, as it currently does. We integrated contacts' remarks into what might be considered savings assurance through a systematic, adaptive management approach to acquiring efficiency savings in the face of risk.

According to contacts, this adaptive management incorporates both site-specific M&V and the alternatives to M&V, assuring the savings previously discussed. The adaptive management approach to assuring savings is, however, more than simply making use of these options (site-specific M&V, program design, savings calculators, deemed savings, and evaluation).[23] Rather, it positions these options within a research agenda whose goal is to reduce over time the risk associated with savings acquisition.

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23 While deeming does not in itself assure savings, it represents a regional consensus that savings from the measure are assured.

In an adaptive management approach, contacts describe a more selective use of M&V than is currently done. BPA would require site-specific M&V only for three targeted purposes:

1. **The assurance of savings for projects with very large energy savings at a single site**
2. **The assurance of savings for projects involving identical technologies or end-uses that, when considered in aggregate regionally, have large energy savings**
3. **To obtain the data necessary to support an analysis of the drivers of energy consumption for applications with significant savings potential region-wide**, so that over time BPA can move to the alternative savings assurance approaches of program design, savings calculators, deemed savings, and evaluation

Of course, as the saying goes, "the devil is in the details." To be determined are such elements as defining "very large energy savings," and "large energy savings in aggregate regionally." Also to be determined are the appropriate protocols for each of the three purposes. As follow-on research to this report, we will be conducting the analyses of BPA's project data necessary to propose definitions; and subsequently, our team will be revising or developing a number of protocols for BPA's consideration.

Under an adaptive management approach, according to some contacts, the region can accept more risk early in the rate period; that is, the region can engage in efficiency implementation in spite of its savings uncertainty while conducting targeted M&V as enumerated above. Having accepted this risk, BPA would true-up savings estimates through evaluation, measurement, and verification activities (collectively referred to as EM&V), allocating savings-assurance efforts to the activities that generated the most expected savings, with a consideration of the historic deviation of expected from actual savings estimates (a measure of uncertainty and thus risk).[24] Making use of the findings of a research agenda, BPA would devise and revise as warranted savings calculators, implementation requirements, and savings assurance activities. However, other contacts cautioned that such an approach would not work for a short-term, two-rate period such as BPA is currently in. These contacts believe frequent programmatic changes would potentially confuse BPA's customer utilities.

Advocates for an adaptive management approach, as just sketched, suggest that BPA initiate some resource acquisition activities as pilots, following a quasi-experimental design with pre- and post-data collection. Other activities might use savings calculators, with a plan to adjust the calculators as warranted over time. The EM&V methods (including use of deemed values) should vary with the delivery mechanism, as that influences the savings realization rate. Utilities should be allowed flexibility in their delivery, yet the allowable deemed values or EM&V methods should reflect the delivery method. Small utilities could be encouraged to work

24 Note that this analysis of matching resources to expected savings and risks requires BPA to understand the cost of its current M&V requirements. See the section *Tracking M&V Activity*, above.

collectively, such as is done by utilities participating in the Idaho Energy Efficiency Agreement (IDEEA), by being allowed to use a simpler EM&V approach for a given application than might be required if a single utility undertakes the application in isolation.

Contacts describe the use of EM&V to build up knowledge of measure savings. Data might be collected on a sample drawn retrospectively, as is done in many evaluation studies, or as part of quality control procedures that sample a census of early projects (by utility, or by consulting engineer) and a decreasing proportion of subsequent projects. EM&V would assure such conditions as adherence to program implementation and EM&V procedures, persistence of savings, performance of the largest regional players (utilities and consulting engineers), as well as measure savings. It would also, as discussed, yield an analysis of the key drivers of energy consumption for an application to foster the development of savings calculators, deemed savings, and streamlined EM&V methods.

Collectively, BPA's EM&V effort, as envisioned by contacts, would draw upon national developments and undertake the research needed to apply (perhaps with adjustments) national findings to the region.

Decision Framework and Tool Library

Contacts noted that BPA does not provide utilities and consulting engineers with a framework and tool library for understanding and conducting M&V. A decision framework and tool library would support even inexperienced engineers – which contacts note will be increasingly called upon to assure regional efficiency savings – in understanding how to think of M&V and design and execute appropriate, defensible M&V plans. For example, a decision framework could help the user understand and implement different M&V approaches for measures with interactive effects and those without, the latter being adequately addressed through simpler methods than the former. It could help the user systematically gather, record, and transmit to BPA data on the key drivers of energy consumption, so that BPA begins to develop databases that can support the derivation of savings calculators and deemed savings values.

The tool library would pull together the M&V site-specific protocols, sampling instructions, formulas, savings calculators and associated instructions, default assumptions, and other elements needed for consulting engineers and field technicians with a widely varying base of experience to, in the words of one contact, "grab it and run with it." The tool library, by incorporating instruction, would address the concern voiced by a number of contacts that savings calculators can be complex, which potentially undermines their reliability.

An M&V decision framework and tool library would thus seek to distill wisdom of the region's most experienced M&V engineers, thereby building M&V capacity, while reducing risk for the region over time with its systematic approach to energy performance measurement.

SUMMARY OF BPA'S CURRENT PRACTICE

Utility contacts are satisfied with existing site-specific M&V protocols for custom projects, the precision levels they believe to be attained, the Light M&V Plan for smaller projects, savings calculators, deemed savings, BPA's M&V documentation requirements, the give-and-take flexibility of BPA's engineering staff, and with the Commercial Lighting and Energy Smart Grocer programs. The interviewed utilities are also satisfied with the expertise of their staff, even though some have concerns about the sufficiency of the numbers of their staff available for energy efficiency work. BPA staff expressed the perspective that "lots of folks in the region are doing M&V correctly."

Contacts both within and outside of BPA expressed concerns about BPA's organizational approach to M&V, including a disconnection between M&V and programmatic efforts, and separations between responsibility and authority for approving M&V plans and the resulting estimates. Several utility contacts also expressed dismay at the difficulty involved in uploading their program data into BPA's PTR database.

Contacts anticipate that many of their concerns about industrial M&V activities will be addressed by the new Energy Smart Industrial program. They also expect that the program's use of a third-party implementation contractor will have the added benefit of allowing BPA engineers to be more available to work with their utility customers.

While satisfaction with the site-specific M&V protocols is high, contacts expressed considerable dissatisfaction with BPA's current approach, which conducts M&V on a high proportion of projects. In addition to the significant effort (and thus cost) this approach entails and the barriers it poses to participation, the approach also necessitates a cadre of experienced engineers. Contacts note these engineers typically are at one or the other end of the career spectrum – approaching retirement age or as new entrants to the field – yet BPA's current approach relies more on individual expertise than a codified, transferable body of knowledge. Consistent with all of these critiques, contacts also expressed dissatisfaction with the limited availability of deemed savings calculators.

CONTACT'S RECOMMENDATIONS

Contacts' recommendations to improve BPA's efforts to assure efficiency savings are listed below.

Changes to M&V Methods

➡ **Reduce the proportion of projects subject to the Standard M&V Plan,** increasing the proportion of projects covered by the Light M&V Plan, savings estimation calculators, and deemed savings.

- **Consider developing savings calculators** for such applications as commercial rooftop HVAC units, data centers, commercial retrocommissioning, ASDs, motors, blowers, fans, pumps, air compressors, and grocery refrigeration floating head pressure controls. Contacts thought the region collectively, and some M&V engineers specifically, may have much of the knowledge needed to support the development of such calculators.
- **Consider adding prescriptive measures** for commercial lighting and some types of new construction, especially fast food restaurants.
- **Pursue an evaluation and M&V research agenda** aimed towards reducing the uncertainty associated with applications making the largest contribution to savings (individually and regionally) and reducing the uncertainty over time by building knowledge of measure performance in varying circumstances. Use this knowledge to change the classification of appropriate project types from custom requiring the Standard M&V Plan to custom requiring Light M&V, deemed savings calculators, or deemed savings.

➡ **Update the *Blue Book* with sub-metering information.**

Changes to M&V Processes

➡ **Track engineer time by M&V project and consider the cost of M&V when developing M&V methods by application**, to ensure M&V efforts are warranted by potential cost savings.

➡ **Track meters in use in the field for M&V and track their operating condition.**

➡ **Streamline approval processes by aligning responsibility and authority for M&V plans and resulting savings estimates.**

➡ **Simplify requirements for uploading utility data into the PTR database.**

➡ **Standardize variables used in the PTR database to provide uniform reports.**

➡ **Provide partial payment when a measure is installed, the remaining payment when M&V is completed.**

➡ **Bring together the regions' M&V protocols and savings assurance tools (such as sampling instruction formulas, default assumptions, key reference materials, and deemed savings calculators) in a single repository.**

5 GAP ANALYSIS OF BPA'S M&V PROTOCOLS

In this chapter, we assess BPA's M&V protocols in light of national M&V best practices and in light of BPA's current energy efficiency activities. Our assessment reflects the progress in the M&V field since BPA first published *Site Specific Verification Guidelines* in 1992.

GAPS RELATIVE TO NATIONAL M&V BEST PRACTICES

We begin this section with a summary of national best practices, which we define as M&V that is IPMVP-adherent – that is, incorporates the requirements delineated in the IPMVP. We then offer suggestions as to how BPA might conform its M&V protocols to current best practices.

National M&V Best Practices

While the IPMVP is specific in describing its fundamental principles, it is worth noting that to accommodate the widest array of energy-efficiency and energy-conservation projects possible, the document was written to allow a great amount of flexibility in its application. Thus, there are many possible approaches and methods with which to conduct an M&V project that fulfills the fundamental IPMVP requirements. We use these fundamental requirements to define M&V best practices.

The fundamental requirements of an IPMVP-adherent process are:

1. **Prepare an M&V Plan**. Once ECMs or projects have been identified and the affected systems or facilities are known, document the requirements for carrying out a successful M&V project with a site-specific M&V Plan. IPMVP defines several items that should be documented in the Plan:

    a. Describe the ECM or project's intent.

    b. Select the measurement boundary and IPMVP Option.

    c. Define the baseline period, energy use, and conditions.

    d. Define the reporting period (post-installation period). [Note: IPMVP-adherent methods report savings only for the reporting period.]

    e. Declare the conditions against which all energy measurements will be adjusted.

    f. Describe the analysis procedure, including data used, algorithms, and adjustments.

    g. State the energy prices to determine energy cost savings.

h. Specify the meters and instruments to be used.

i. Define the roles and responsibilities of involved parties.

j. Evaluate the expected accuracy of the savings analysis.

k. Define the budget for M&V activities.

l. Specify how results will be reported.

m. Describe quality assurance procedures.

2. **Document the Baseline**. Document the as-found conditions and energy use of the buildings and systems from which savings will be measured. Comprehensive baseline documentation includes not only collecting energy-use and other data through short- and longer-term measurements, but also compiling a complete inventory of equipment, operating schedules, and parameters, and identifying independent variables that influence energy use. Deficiencies in system performance that will be corrected through installation of ECMs must be identified. ECMs must describe how they will reduce energy use in the facility. As much information as possible (e.g., data, inventory lists, and photos, etc.) should be included to support baseline documentation. Baseline energy use data must be collected over the agreed-upon duration according to the project's M&V Plan.

3. **Verify ECM or Project Installation and Effectiveness**. Verify that the installed ECMs are commissioned or are operating as intended and that their operations are in fact an improvement over the baseline conditions. Use inspections, photos, spot and short-term measurements, and functional testing to verify improved operations of systems and equipment.

4. **Verify Savings**. Measure energy use for the agreed-upon time period after an ECM or project has been installed, and make adjustments so that this energy use can be compared under the same set of conditions as the baseline. Account for any unexpected variance (e.g., operating hours or occupancy rates) in the facility that affect post-installation energy use that was not present in the baseline period. Document savings results for the specified post-installation period.

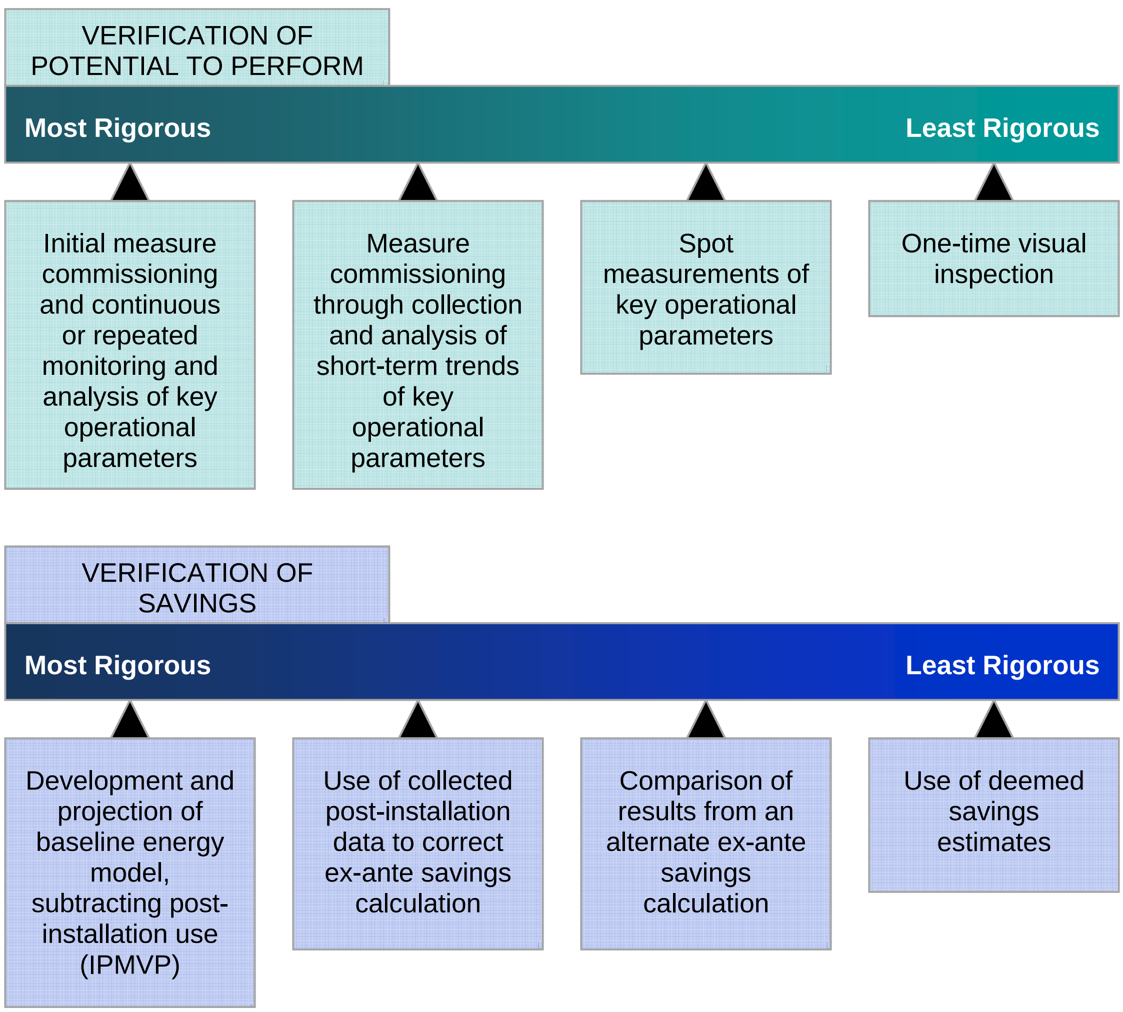
5. **Periodically Measure and Verify Performance**. This step is essentially the same as the previous two steps, except that an energy management program is put in place to continuously or periodically repeat ECM commissioning activities and energy use measurements to verify that the improved systems continue to operate effectively and that energy savings is realized continuously.

As described in the outline above, IPMVP fundamentals require two elements of verification:

1. Verification that the measure or project has the potential to perform (is installed and operating correctly); and
2. Verification that energy savings is occurring.

Several commonly used verification methods apply different levels of rigor in these two verification categories, including the current BPA methods. Figure 5.1 provides a representation of the spectrum in rigor levels for each of these verification elements, and also qualitatively shows where certain commonly used verification activities fall in relation to each other. IPMVP Best Practices clearly tend toward the most rigorous end of these spectra.

Figure 5.1: Spectrum of Rigor Levels in Savings Verification



M&V best practices also recognize the importance of balancing the expected benefits of various degrees of M&V project rigor and with the expected costs of attaining that rigor. Both rigor and cost typically increase with greater numbers of measurement points, shorter intervals of observation (i.e., 15-minute data), longer durations of monitoring, and increases in the analytical skills typically needed to draw valid interpretations of the data. Factors that mitigate these costs should be considered, such as the presence of existing monitoring systems, availability of utility and weather data, and the simplicity of the systems and equipment being modified by the efficiency project. One might assume that the greater the expected magnitude of savings as a percentage of annual energy use, the more important it is to pursue rigor with its attendant costs; yet it may be possible to demonstrate savings in this situation with a less granular or detailed level of metering and analysis.

M&V professionals recognize that ideal application of the IPMVP is not achievable in all cases. Some projects will not have the resources or budget to complete rigorous M&V methods. Generally, projects with the potential to generate significant savings will be better candidates for rigorous M&V methods. Nevertheless, with the advance of new technologies – such as wireless sensors and mesh networks, smart grid monitoring technologies, incorporation of energy monitoring points in technologies such as variable speed drives, and development of web-based tracking databases and tools – the threshold project savings above which M&V is cost-effective will be driven lower and will become more widespread. It would serve BPA's interests well into the future to push its protocols toward best practices as defined in the IPMVP.

Conforming BPA Protocols to Best Practices

Most of the existing BPA M&V protocols conform to the principles of the IPMVP and therefore can support a best-practice M&V program. In form and presentation, they also have the look and feel of protocols developed for peer programs in the United States. However, the protocols fall short of the level of detail required to guide users through the common issues encountered when putting them into practice. As a result, they allow potential misinterpretation or misapplication.

BPA can build on the existing protocols to better guide nontechnical users through the M&V process and improve the reliability of project savings reports. To keep the protocols user-friendly, the improved versions should be no more than ten pages long; in many cases, five or six pages may suffice.

Because the region developed many of the protocols prior to the IPMVP, it is no surprise that many of the protocols do not reference the IPMVP Options. Fortunately, the substantial similarity between the BPA and IPMVP documents supports a straightforward identification of opportunities to refine or augment BPA's protocols.

We describe our findings of "gaps" in terms of recommendations. We recommend for each protocol that BPA:

1. Identify the IPMVP Option (A, B, C, or D) the engineer should use and describe how the option would be used or tailored to the application.

2. Add to the protocols' requirements documentation of baseline equipment and baseline operational characteristics.
3. Expand the description of the calculations to be used, including describing the data to be collected and how the data are to be used in the calculations.
4. Describe how uncertainty will be developed in the baseline energy models and post-installation measured use, and how to estimate the resulting savings uncertainty.
5. Describe site-specific ECM commissioning requirements, as BPA does with its industrial compressed air projects through the TSP vendors.
6. Describe tradeoffs or opportunities that make each protocol more cost-effective.
7. Specific features that should be added to each protocol include:
    a. Algorithms to calculate savings and the necessary interim calculations
    b. Guidance on when to use sampling
    c. Content and form of an M&V report
    d. Accounting for baseline adjustments

We note that some of the Regional Technical Forum protocols confuse project-level M&V with program impact evaluation; or, in the case of Group No. 3, apply only to evaluation. The protocols should be modified to apply only to the calculation of site-specific project savings.

BPA's existing M&V protocols and methods take differing approaches to verifying savings, based on market sector, load characteristics, use of energy metering, and other factors. Various levels of rigor in metering, baseline definition, calculations, and other activities are implied in these protocols. BPA should make explicit its desired precision levels, possibly presenting a graphical decision tree that enables the practitioner to identify the appropriate level for the given application. The appropriate precision level depends on the characteristics of the resource relative to the total resource portfolio.

GAPS RELATIVE TO REGIONAL SAVINGS ASSURANCE NEEDS

Considering BPA's protocols in light of its programs and the comments of interviewed regional stakeholders, BPA would benefit from developing the following new protocols:

- ➡ **Existing Building Commissioning**
- ➡ **Packaged Commercial HVAC** – protocol and/or savings calculator (for smaller ton units)
- ➡ **M&V Protocol Selection** – providing guidance on selecting the appropriate M&V protocol for the measure and site

- **Sampling**
- **Regression** – providing guidance for analyzing time-series data in support of site-specific M&V of a custom project

In addition, BPA should continue to assess whether an M&V protocol would be useful for grocery store refrigeration.

Existing Building Commissioning M&V Protocol

Existing building commissioning (EBCx) projects follow a process to identify deficient system operations in buildings. Correcting these deficiencies leads to cost-effective, typically large, savings. At issue is the longevity of these savings, as many of the corrections (i.e., control system programming, set point or schedule settings) are software based; if they are not monitored and adjusted appropriately, they can revert to inefficient operation.

Two approaches to the implementation of M&V in EBCx projects emerged:

- **A traditional and common energy efficiency program practice in which savings for each individual EBCx measure is estimated prior to implementation (engineering calculations); and, after installation, operational data are collected to verify that the systems are operating better**. If that is true, then the ex-ante savings are accepted. If not, the calculated savings are adjusted with actual post-implementation conditions. This is similar to BPA's Light M&V Plan.
- **A systems performance approach in which the energy savings for all improvements identified in the EBCx process for each subsystem in the building are verified collectively**. This approach acknowledges that EBCx is a *process*, not a collection of *measures*, and that the EBCx M&V process can establish monitoring procedures that can be used to train building operators on tools to continuously monitor and improve system operations, while providing robust IPMVP-adherent M&V cost-effectively. Examples include the UC/CSU/IOU[25] Partnership's Monitoring-Based Commissioning Program in California.[26]

We bring to BPA's attention the conclusions of a report sponsored by the California Commissioning Collaborative (CCC) that many of the activities involved in commissioning and M&V overlap, and that much of the data collected before and after the ECMs were installed could be used for M&V. We encourage BPA to keep abreast of findings from the CCC's

25 The University of California (UC), California State University (CSU), and Investor-Owned Utility (IOU) Energy Efficiency Partnership is a statewide energy efficiency program. See: *http://www.uccsuiouee.org/.*

26 See the California Commissioning Collaborative (CCC) *Guidelines for Verifying Existing Building Commissioning Project Savings*.

ongoing follow-up Verification of Savings project. In this follow-on project, the CCC intends to provide additional M&V guidance, using different IPMVP-adherent and non-adherent methods.

Packaged Commercial HVAC M&V Protocol

Both BPA contacts at our kick-off meeting, as well as those we interviewed for the research, indicated a need for an M&V protocol for packaged HVAC equipment. Alternatively, the region might benefit from a savings estimation calculator for small packaged units (size to be defined, but perhaps less than 50 tons).

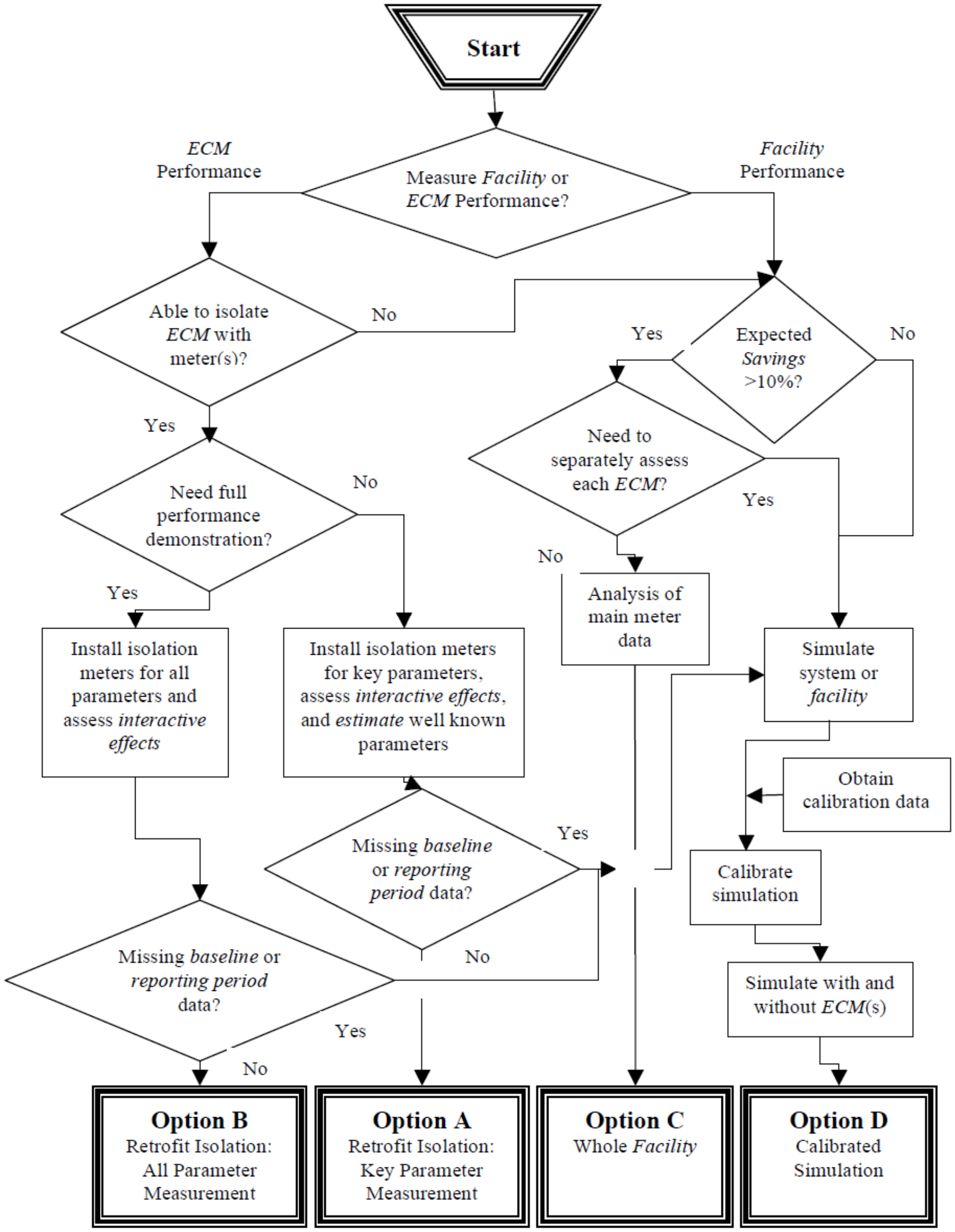
A packaged HVAC protocol must be consistent with the program design and actual measures. For an equipment replacement measure in which a high-efficiency packaged unit replaces an older inefficient unit, the M&V typically involves a regression analysis of energy consumption against average outside air temperature. If the program measures include equipment tune-ups, BPA will be able to adopt the M&V protocol being prepared by the RTF for packaged HVAC tune-up measures. It is likely the RTF's protocol will include the space type served by the packaged unit as an analytical variable.

M&V Protocol Selection Tool or Protocol

Based on our review of BPA documents and the comments of interviewed stakeholders, it appears that BPA does not have a document that describes to users of the existing M&V protocols how to select the most appropriate one for a given task.

The M&V protocol selection tool would be a protocol describing in text and graphics a decision framework for choosing a savings verification approach that will result in a project savings report meeting program reliability standards at minimum cost. The selection protocol would be presented early in a document with all of BPA M&V-related protocols. An example graphic from the IPMVP is shown in Figure 5.2. Note that this decision framework applies only to IPMVP-adherent options; BPA would likely also include verification options, such as deemed savings with onsite verification.

Figure 5.2: IPMVP Savings Verification Selection Tool



Sampling M&V Protocol

Sampling is an important technique used by M&V professionals when developing cost-effective and reliable savings estimates for large populations of equipment in energy efficiency projects, such as lighting retrofits. The addition of sampling to BPA M&V protocols can help bring them in line with national best practices

Energy-efficiency programs commonly include guidance on sampling because the reliability of the estimated savings requires the correct application of statistical techniques that are not normally encountered by contractors and engineers. BPA can address this gap by creating a sampling protocol that is referenced in measure-specific M&V protocols, and which describes in a step-by-step fashion the process for selecting a representative random sample on which to conduct the M&V activities. One example is the FEMP M&V Guidelines, which we have included in Appendix B.

Regression M&V Protocol

In conducting site-specific M&V for custom projects, the engineer often must acquire time-series data from on-site metering, weather conditions, records of industrial output, and so on. Regression analyses enable the engineer to determine the relationship between energy use and the variables that drive it, including time. BPA's engineers would benefit from a regression protocol that provides guidance on such things as evaluating the significance of the independent variables and the uncertainty of the regression.

Grocery Store Refrigeration M&V Protocol

BPA staff are considering whether they have a need for a standalone M&V protocol for the EnergySmart Grocer program, which is implemented for BPA by a contractor.

Depending on the program design, mix of measures, and magnitude of expected savings, a protocol could address the requirements for M&V at the whole-building (IPMVP Option C) or end-use device level (IPMVP Option B). Because utility meter data capture the performance of all end-uses (such as lighting, HVAC, and refrigeration), such data would be appropriate for comprehensive retrofits. Billing data from supermarkets typically exhibit small variance compared to other building types, so it is possible to use this approach to create models that estimate savings with acceptable uncertainty levels.

Refrigeration measures often make up a significant portion of any grocery store energy efficiency project. If this class of measures accounts for a significant portion of the program savings, then an end-use M&V protocol focusing on refrigeration may be warranted. Typical end-use refrigeration M&V involves regression analysis in which refrigeration rack energy consumption is regressed against outside air temperatures, indoor humidity levels, and time of day. Refrigeration M&V usually requires interval demand data and therefore involves installing metering equipment. The RTF approved a regression approach for a grocery M&V pilot program, and any BPA protocol should incorporate the RTF's recommendations.

ADDITIONAL CONSIDERATIONS FOR M&V

M&V Rigor and Risk

An M&V approach should be pursued only if the value of the reduction in uncertainty it yields exceeds its cost. In some situations, no project-level M&V will be appropriate.

Based on our interviews, BPA engineers typically weigh the cost and value of the M&V as they decide the M&V requirements for specific projects, although they do this informally. BPA should build on the IPMVP to develop a framework by which the decision can be made more formally and rationally.

Uncertainty in a savings estimate is partly a function of the variability in the energy use from one application to the next. To address this, IPMVP classifies projects as having high or low *energy variation* and high or low *value*.

To demonstrate this concept, we offer the example of a lighting retrofit project in an industrial building. Two possible approaches to determining the savings from the project are:

1. **Verification –** Verify, through a pre-installation inspection or interview with onsite personnel, the type of baseline fixtures, and the quantities and operating hours of each. Conduct a post-installation inspection to verify the type and quantity of fixtures installed. Estimate the watts per fixture based on standard lighting tables. Estimate the hours of operation based on an interview with onsite personnel. Project energy savings is the change in lighting wattage times the operating hours.

2. **M&V using IPMVP Option B –** Verify, through a pre-installation inspection, the baseline, types of fixtures, and quantities of each. Conduct a post-installation inspection to verify the types and quantities of new fixtures installed. Determine baseline and post-installation wattage by taking spot power measurements of a sample of lighting circuits. Measure the hours of operation with light loggers installed on a sufficient sample of fixtures. Project energy savings is the change in measured lighting wattage times the measured operating hours.

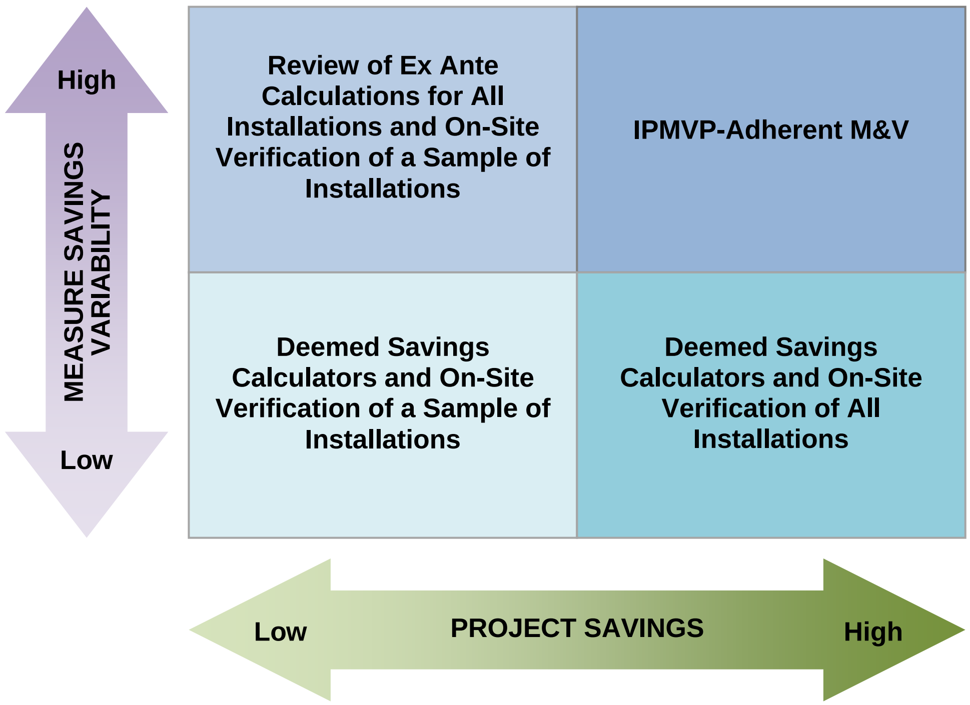
To balance cost and rigor, Option 1 is likely to be the best choice for most small- and mid-sized lighting projects. The metering costs required for Option 2 become justified only if the savings for the project are relatively large. Even in a project with large savings, Option 1 may be justified if the two variables that would be measured can be estimated with reasonable certainty without metering. In this example, if the hours of operation of the facility are continuous, or are otherwise known with a high degree of certainty, there is little to be gained from installing light loggers. Similarly, if the fixtures are of a standard configuration, it is appropriate to use watts per fixture based on standard lighting tables.

IPMVP provides guidance on the recommended cost of M&V as a percentage of the value of savings (less than 10%) and states that:

> "…the quantity of savings at stake therefore places a limit on the M&V budget, which in turn determines how much uncertainty is acceptable."

Note that this language is most relevant to M&V conducted in support of a performance contract. In a utility program setting, the uncertainty likely is set by the portfolio impact evaluation goals. In a utility program, administrators help project implementers select an M&V approach that will support the program reporting accuracy requirements, but will do so at minimum project M&V costs. Figure 5.3 presents this spectrum of choices graphically.

Figure 5.3: Recommended Savings Verification Approaches



Impact Evaluation

As some of our interview contacts pointed out, impact evaluation differs from M&V, although M&V plays a role. Impact evaluation assesses program and portfolio-level savings; M&V assesses projects. The information collected through the project-level M&V process allows a correct accounting of program performance that minimizes the risk of error in reported savings – both the *ex ante* savings reported in implementation databases and the *ex post* savings reported in impact evaluations. From a program perspective, appropriate M&V supports the accurate assessment of progress towards goals, which ultimately is measured through an impact evaluation.

Impact evaluations can also address issues such as savings persistence and savings variation across measures and time. Using a strategic approach to impact evaluation over time, one can build knowledge, and refine program and project requirements and processes to reduce risk. As mentioned by some of our contacts, an impact evaluation strategy can pursue a research agenda.

Controlling for uncertainty is a significant issue in impact evaluations. Therefore, one section of an impact evaluation strategy addresses uncertainty limits. Uncertainty in reporting program results arises from the fact that energy savings – the absence of energy use – cannot be measured directly. Savings are calculated as the difference between the energy use for an efficient case minus what would have been used in the absence of the efficient case (the baseline condition), controlling for changes between the baseline and post-installation conditions that are independent of the efficiency measure, such as changes in weather temperatures, operating schedules, and industrial output.

Savings estimates at the program (evaluation) level are subject to two types of quantifiable errors:

- **Systematic error** results from decisions or actions taken by the evaluator. Examples are modeling and measurement error, or bias that excludes an affected portion of a population from a review.
- **Sampling error** occurs by chance whenever a random sample of a population is examined and the results extrapolated to the entire population.

While systematic error can be quantified, in practice evaluators generally identify its sources and then work to prevent or minimize its occurrence. Impact evaluators traditionally have not reported uncertainty associated with systematic error.

Sampling error, on the other hand, always is quantified as uncertainty relative to the point estimate for actual savings. An example is "the best estimate of savings for the measure is 10,000 kWh/yr ±10% at the 90% confidence level." Impact evaluators report results as a point estimate (10,000 kWh/yr in the example), precision (±10%) and confidence level (90% in the example.) Reducing uncertainty is primarily a function of using larger sample sizes, which always results in additional cost.

Savings estimates also are subject to unquantifiable errors arising from lax quality control. Examples are inaccurate data entry into a program-tracking database, or erroneous assumptions about the number of operating hours per year for lighting projects. The resulting errors are real and, if made by program administrators, can be a significant contributor to impact evaluation adjustments. Quality control errors might be recognized as contributing to uncertainty about a true savings estimate, but the degree of uncertainty can be reported only in subjective terms.

To lay the groundwork for an impact evaluation strategy, the evaluator would review the sources of uncertainty in program-reported results, probably through a Monte Carlo analysis, or the evaluators' experience with similar programs. The sources of uncertainty might include:

- ➡ Magnitude of expected savings
- ➡ Size of expected savings relative to baseline
- ➡ Measure type
- ➡ Program type and maturity

The review undertaken in support of a strategy would conclude with a list of the error sources, ranked by the probability that they might contribute to the total program uncertainty. Projects would be assessed in terms of their potential for savings uncertainty, given this understanding of the error sources.

An impact evaluation strategy also would specify a threshold sampling error, such as 90% confidence at 10% precision or better.

With respect to the conduct of project-level M&V, an impact evaluation strategy sets out expectations for reporting accuracy, and identifies sources contributing to the uncertainty in savings estimates and the comparative impacts of the sources. This information is fundamental to developing a M&V selection protocol for selecting a savings verification approach at the project level.

6 CONCLUSIONS AND RECOMMENDATIONS

Our research has found that BPA's site-specific M&V protocols are generally working well from a process perspective, and contacts have confidence in the measured and verified savings. Nonetheless, there are opportunities for revisions to bring the protocols into closer alignment with M&V best practices, as we detail in our recommendations, below.

As BPA anticipated in its RFP for this research, the region would benefit from having additional protocols, as recommended. Based on our review and interviews, there appears to be a need to articulate to BPA staff and utility customers the reasons for conducting M&V, the expectations for rigor, and the standards by which M&V is conducted.

While satisfaction with the site-specific M&V protocols is high, contacts expressed considerable dissatisfaction with BPA's current approach that designates as custom many projects, thus requiring the conduct of M&V (and in particular, the Standard M&V Plan, in contrast to the Light M&V Plan) on a high proportion of projects. In addition to the significant effort (and thus cost) this approach entails, and the barriers it poses to utility and end-user efficiency efforts, the approach also necessitates a cadre of experienced engineers. Contacts note these engineers typically are at one or the other end of the career spectrum – approaching retirement age or as new entrants to the field – yet BPA's current approach relies more on individual expertise than a codified, transferable body of knowledge. Consistent with all of these critiques, contacts also expressed dissatisfaction with the limited availability of deemed savings calculators.

Thus, contacts are in general agreement that the region would benefit from efficiency savings assurance measures that decrease the proportion of projects requiring the Standard M&V Plan and increase the proportion governed by the Light M&V Plan, deemed savings estimation calculators, and deemed savings.

Finally, we have reached the conclusion that BPA will best attain its objectives for assuring energy efficiency savings while reducing the burden of M&V by evolving in tandem its M&V policies and procedures, and its evaluation strategy and activities. Through a combination of M&V and evaluation activities conducted over time, BPA can better understand the risk attending the various efficiency activities, identify programmatic activities to minimize this risk, and increase the proportion of projects whose savings are able to be assured through deemed savings, deemed calculators, and Light M&V.

Among the significant findings of our research are those facets of BPA's M&V activities about which we remain unable to comment. These include the proportion of projects eligible for Light M&V, yet for which the M&V engineer followed a standard M&V protocol, and the proportion of BPA's total custom project savings measured and verified with each protocol. We pursued both of these analyses, but the data provided by BPA were insufficient for us to estimate these proportions.

We undertook the proportional analyses to address one of BPA's research questions for the current work: to recommend an appropriate kWh threshold for the Light M&V Plan (either confirming the choice of 200,000 annual kWh or recommending a new value). Unfortunately, the determination of a threshold as "appropriate" does not derive from experience or best practices, but must rest on the analysis of the projects themselves. For this, it is necessary to conduct a risk analysis, considering: the individual project size; the proportion of total portfolio savings comprised by all projects of that type; and the variation in pre-installation savings estimates from the post-installation estimates. In response to the initial draft of the current report, BPA now plans to pursue this research under a separate contract.

We offer the following recommendations.

- ➡ **Revise the existing protocols to add detail regarding M&V activities**, such as sampling, calculation of savings, selecting monitoring points, and generally addressing questions that arise when practicing M&V. We recommend that the revised M&V protocols follow the guidance provided by the International Performance Measurement and Verification Protocol (IPMVP), so that BPA's M&V practices are IPMVP-adherent. The recommended revisions include such things as: identifying the IPMVP Option (A, B, C, or D) the engineer should use; requiring documentation of baseline equipment and operational characteristics; and expanding the description of the calculations to be used, including describing the data to be collected and how the data are to be used in the calculations. Revision of the protocols will also enable BPA to specify more robust M&V techniques supported by advanced metering technology that was formerly cost-prohibitive.
- ➡ **Develop or revise five or six of the following protocols** in the remaining portion of this research contract. (The contract specifies that five or six protocols will be developed or revised.)
    - ***End-Use Metering*** – revision of an existing protocol
    - ***Energy Use Indexing*** – revision of an existing protocol
    - ***Existing Building Commissioning*** – a new protocol
    - ***Packaged Commercial HVAC*** – a new protocol
    - ***M&V Protocol Selection*** – a new protocol providing guidance on selecting the appropriate M&V protocol for the measure and site
    - ***Sampling*** – a new protocol
    - ***Regression*** – a new protocol for analyzing time-series data in support of site-specific M&V of a custom project

➡ **Conduct research subsequent to this project** to determine the proportion of projects that received standard M&V in spite of their eligibility for Light M&V, and the variance of post-installation savings estimates from pre-installation estimates by measure type and size category. Based on this investigation, the subsequent research should recommend an appropriate kWh threshold or alternative thresholds corresponding to measure type or other decision criteria for invoking the Light M&V Plan.

➡ **Require M&V engineers to conduct Light M&V for all eligible projects.**

➡ **Bring together the regions' M&V protocols and savings assurance tools (such as sampling instruction formulas, default assumptions, key reference materials, and deemed savings calculators) into a single repository.**

➡ **Improve documentation of M&V activities** (time spent and protocol used by project) **and entries in the Planning, Tracking, and Reporting (PTR) system** (measure type, pre- and post-installation savings estimates, and protocol used) to support M&V activities throughout the region and facilitate risk-reduction analyses**.**

➡ **Take steps to address problems stakeholder contacts indentified in the conduct of M&V.** Consider actions to address the following:

- Align responsibility and authority within BPA for approving M&V plans and the resulting savings estimates.
- Simplify the processes by which utilities upload their efficiency information into BPA's PTR database.
- Bring cost documentation requirements in line with risk, so that requirements focus on higher-cost project elements rather than all cost elements.

➡ **Coordinate the evolution of BPA's M&V policies and procedures with the evolution of its evaluation strategy and activities.** M&V and evaluation should work in tandem to understand the risks attending BPA's efficiency resource acquisitions, and to understand how to address those risks in a cost-effective manner through: IPMVP-adherent M&V protocols; Light M&V; deemed savings estimation calculators; deemed measures; programmatic approaches; and evaluations of programs and measure types. For example, BPA has the opportunity to conduct a meta-evaluation of the M&V analyses of custom projects of a similar type, assessing the findings for variance of post-installation estimates from pre-installation estimates, and for relationships among the drivers of savings and the savings estimates. For project types for which there is small variance and/or the relationships between savings drivers and savings outcomes appear evident, BPA might consider classifying the project type as eligible for Light M&V or developing a deemed savings calculator.

APPENDICES

APPENDIX A: BIBLIOGRAPHY OF M&V PROTOCOLS AND GUIDELINES

APPENDIX B: SAMPLING PROTOCOL FROM FEMP M&V GUIDELINES

APPENDIX C: INTERVIEW CONTACTS AND INTERVIEW GUIDES

A BIBLIOGRAPHY OF M&V PROTOCOLS AND GUIDELINES

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B SAMPLING PROTOCOL FROM FEMP M&V GUIDELINES

The following is *Appendix B Sampling Guidelines from the Federal Energy Management Program M&V Guidelines: Measurement and Verification for Federal Energy Projects, Version 3.0.* (See: *http://www1.eere.energy.gov/femp/pdfs/mv_guidelines.pdf.)*

B.1 INTRODUCTION

This appendix introduces the statistical background, theory and formulas used to select, analyze and validate samples for project monitoring and evaluation. It also provides guidelines and procedures for the design and implementation of sampling.

B.1.1 Sampling

The purpose of monitoring a sample, as an alternative to monitoring an entire population is to; (a) characterize particular attributes of a population from which a sample is drawn with adequate accuracy and reliability, while (b) reducing monitoring costs and effort.

As shown in Figure B-1, sampling involves selecting several members from a population for monitoring and evaluation. The measured characteristics or behavior of the sample group is then used to infer the characteristics and/or behavior of the entire population. As expected, the assumption is that the sample is representative of the population. To ensure that the sample is indeed representative, calculations must be performed to assess and quantify the statistical validity of the sampled data. These calculations are presented later in this Appendix.

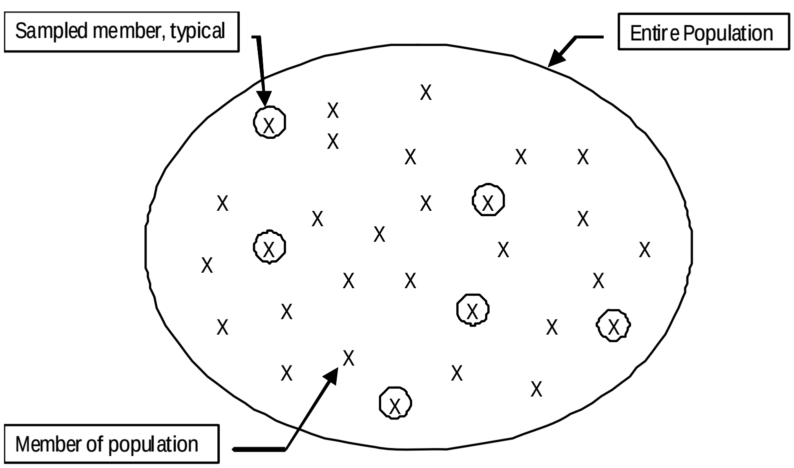

Figure B-1 Population and Sample

Sampling is applicable to projects such as lighting retrofits, energy efficient motor replacements, HVAC unit replacement, steam-trap monitoring, or any other project in which a number of similar pieces of equipment are affected by the same type of ECM. In the most common applications, sampling strategies are used to characterize the hours of operation and the instantaneous power draw of a constant-load device. A separate sample set is required for each item evaluated.

When selecting a sample from a population to determine hours of operation, it is necessary to ensure that the load is or device being sampled is monitored at or down-stream of its last point of control (LPC). The last point of control (LPC) is the portion of an electrical circuit (or other source of energy), that serves a set of equipment that is controlled on a single switch. As a result, all of the fixtures or pieces of equipment on that LPC are typically operated the same number of hours per year. For metering purposes, it is assumed that measurements taken of a single piece of equipment on an LPC captures the operating hours for all of the equipment served on the same circuit.

B.2 MATHEMATICAL METHODS FOR SAMPLING

Sampling must be conducted using accepted methods and use an appropriate level of care to ensure that the M&V results that rely on the sampling and analysis are sufficiently accurate. This section provides a summary of the concepts, methods and equations to be used.

Although various assumptions regarding the distribution of the sampled data can be made, the large majority of sampling statistical analysis assumes that the data is *normally distributed* about the *mean* and in this Appendix, this assumption is made.

Statistical validity requires that the samples be randomly selected. Use of a random number generator, such as that found in MS Excel™ is convenient for ensuring the sample is randomly selected.

B.2.1 Point Estimation – Confidence and Precision

When we use sampling to estimate an average value of an entire population, we are performing an activity know as *point estimation.* A value or 'point' that is estimated based on a sample is not the actual average value but rather, is a value that is "reasonably close" to the actual average value. The question, then, for the M&V practitioner is: "What do we mean when we say 'reasonably close'?" The question is answered using the following statistical terms.

- Confidence: Confidence is fundamentally the same as probability, except that confidence refers to data already obtained, while probability refers to a future value. A confidence of 90% is commonly used in M&V. So, using our 90% example, when we refer to a confidence level, we are saying "I am 90% *confident* that the measured value is within my stated *confidence interval*."
- Confidence Interval (or Precision): Because the value estimated by sampling can not be expected to be the actual value, it is useful to state an interval in which we have confidence the true value lies. Confidence interval is also often referred to as *precision*. An M&V practitioner may state that they know the value has a *precision* of 10%, which would mean that the "The estimated is within 10% of the true value."

Confidence and precision, then, are the values referred to when a 90/10 (or 80/20 or any other) criteria is specified.

Example

Imagine that we wish to measure the run-hours of a sample of equipment for a month. Imagine now that we measure 200 'on' hours. If we are hoping to meet a 90/10 criteria, we are hoping that we can say, with a 90% probability, that our estimate is within 10% of the actual average run hours – that is, we are 9/10th sure the actual runtime is between 180 and 220 hours.

To graphically illustrate the concepts of normal distribution, confidence, and precision, Figure B-2 shows a normal distribution with a confidence interval. Note that the confidence interval in the figure is defined by the error (+/- E). This error figure is discussed further below and is defined in Equation 1.

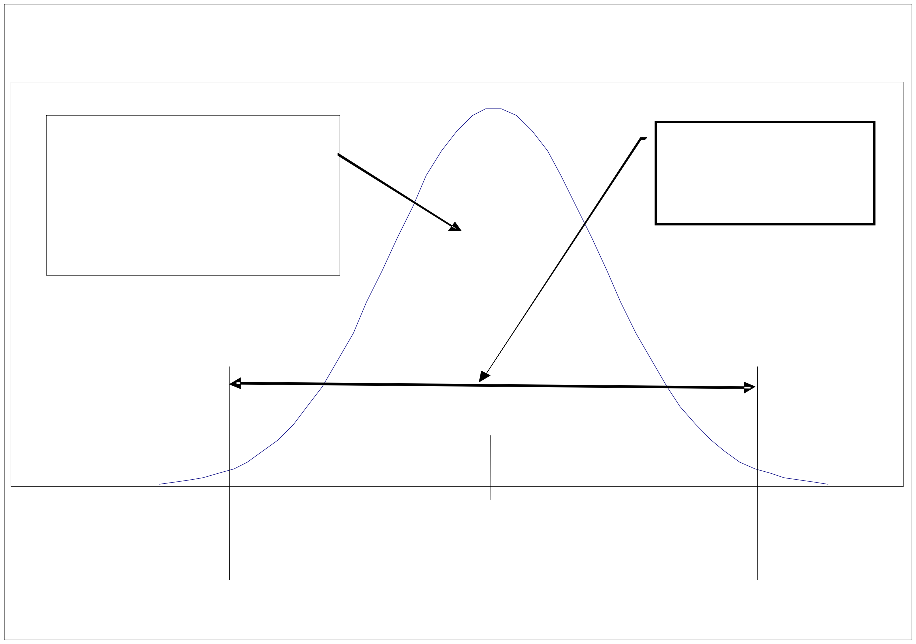

Figure B-2 Normal distribution with confidence interval

The confidence interval (or precision) and the confidence level are positively linked; for any sample, as the confidence interval increases (that is, the precision is reduced, and the range of possible values of the true mean increases) the confidence level increases. Or, looking at it another way, as the confidence interval is reduced, the confidence level is also reduced.

B.2.2 Sample size calculation

When sampling, it is the M&V professional's job to meet certain levels of confidence and precision and to calculate the actual confidence and precision that resulted from a sampling exercise. In order to accomplish this analysis, it is helpful to start with Equation 1, the statistical equation for calculating the *maximum error* in the result. This value is also depicted as 'E' in Figure B-2.

$$E = z \frac{s}{\sqrt{n}} \qquad \textbf{Equation 1}$$

Where:
E = maximum value of error
s = the standard deviation of the sample[1]
n = sample size

[1] Calculating the standard deviation is not defined herein.

z = the z-statistic[2], typically denoted as $z_{\alpha/2}$. Alpha (α), is equal to 1 – % confidence, and is used in most statistical references because it represents the top and bottom tails of the normal distribution, which together bound the confidence level.

The z statistic is a variable that is calculated such that the following equation is true: $z = \dfrac{\bar{x} - \mu}{s/\sqrt{n}}$,

where μ is the population mean (unknown) and $\bar{x}$ is the sample mean. Although the true mean, μ, is unknown, values of z, at various levels of confidence (1 – alpha) are known and are tabulated in many statistics books[3]. Values of z, assuming that the number of samples, n, is greater than 30 are 1.645 for 90% confidence and 1.282 for 80% confidence.

Rearranging Equation 1 we can solve for the number of samples needed to ensure we are within a certain confidence interval:

$$n = \frac{z^2 \cdot s^2}{E^2}$$ **Equation 2**

Note in Equation 2 that the standard deviation of the sample, s, and the maximum allowable error, E, are in the units of measurement, (i.e.: hours or kW). The standard deviation, s, of the sample can be expressed as the *coefficient of variation* (or C_v), which is a fraction of the mean, as shown in Equation 3.

$$C_v = \frac{s}{\bar{x}}$$ **Equation 3**

Where:
$\bar{x}$ is the sample mean

In like manner the maximum error, E can also be expressed as a fraction of the mean, (precision), as shown in Equation 4.

$$P = \frac{E}{\bar{x}}$$ **Equation 4**

Substituting C_v and P into Equation 2, we get a unitless expression, as shown in Equation 5.

$$n = \frac{z^2 \cdot (s/\bar{x})^2}{(E/\bar{x})^2}$$ **Equation 5**

Or expressed another way,

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2 A similar statistic, known as the t-statistic, which assumes a 't-distribution' rather than a normal distribution, and is a function of the number of samples can be substituted for the z static is a more correct approach. Although preferable, for small populations and which exhibit more 'spread' than, for samples large than 30, use of the normal distribution gives a good approximation of the t-distribution. At smaller sample sizes slightly larger samples than are indicated using the normal distribution should be taken.

3 For example: Statistics, 5th Edition, by Robert S. Witte and John S. Witte or Probability and Statistics for Engineers, by Iwrin Miller and John E. Freund

$$n = \frac{z^2 \cdot (C_v)^2}{(P)^2}$$ **Equation 6**

where

Z = Z-statistic, 1.645 for 90% confidence, 1.282 for 80% confidence.

P = Precision required, typically 10% or 20%

Equation 6 is the basic equation used in sample group sizing. For small populations the sample size should be modified using the finite population correction shown in Equation 7. Typically, this correction is required when the population is less than 500. The finite population adjustment calculation gives n^*, which is the new sample size corrected for population size.

$$n^* = \frac{Nn}{n+N}$$ **Equation 7**

Where
n^* = sample size corrected for population size
n = sample size for infinite population
N = population size

A critical step, that is often not completed, is the post-monitoring calculation of the **actual** *standard deviation*, *coefficient of variation*, and subsequent calculation of *precision* at various *levels of confidence* using the above equations. Ultimately, the maximum error (E) using Equation 1 should be calculated for various levels of confidence. No job is complete until these post-monitoring calculations are completed and reported.

B.3 APPLICATION OF SAMPLING TO PROJECTS

In the next sections considerations for the design and application of sampling are explored. The analysis steps to be used in conducting sampling are as follows:

1. *Compile and analyze the project, ECM and M&V Plan Information*
2. *Designate sampling groups*
3. *Select Samples*
4. *Collect and analyze sample data*
5. *Extrapolate the result from the sample over the entire population*

These steps are discussed below.

B.3.1 Compile Project/ECM and M&V Plan Information

In this step, the goal is to fully understand several things, including: the measure scope, the savings calculations quantifying the intended performance, the M&V method to be used and the data to be collected. Once the project is understood, an M&V practitioner can identify the calculation method and select variables to be sampled.

In many energy conservation projects, it is often necessary to conduct both pre and post installation sampling. Regardless of whether the sampling is for evaluating the baseline or the post-retrofit conditions, the following information is typically required to properly assign usage groups and determine sample sizes.

- ***Number of circuits, devices or LPCs.*** Identify and document the LPCs that are affected by the installation of ECMs. This should be provided in the form of an equipment inventory survey in which each line in the survey represents an LPC that includes descriptions of affected and proposed ECM nameplate data and quantity as well as location information.
- ***Actual or change in load or wattage.*** Using the equipment inventory survey, the total change in load or wattage of the affected equipment by usage group can be computed.
- ***Hours of operation.*** Sampling can be used to estimate the average hours of operation of the equipment. After the first sampling period (whether it is a year, month or week) of monitoring, the sampling result (actual C_v, Equation 3) should be used to compute the sample size. If it is expected that the equipment will be used in a significantly different in the current period than it was in the previous period, the estimate may be adjusted.

B.3.2 Designate Sampling Groups

Each device or LPC should be assigned to a usage group based on similarities in the parameter being determined, such as operating hours or connected load. If differences are expected, but there are too few usage groups, the resulting variance of the data may result in unsatisfactory confidence and precision levels. However, if too many usage groups are created, then excessive monitoring and too small of populations may occur. So, while considering the tradeoffs, usage groups should be developed from criteria such as:

- Area type (for example; office, hallway, meeting room)
- Annual operating hours
- Timing / usage patterns of the operating hours, load, or other variable
- Variability of operating hours, load, or other variable
- Similar functional use

Usage groups should be selected so that equipment or LPC's are similar in that the sampled value (for example, hours or kW or kW/unit) is clustered around a specific estimate. When possible, avoid designating usage groups with populations that will yield less than 10 sample points. Examples of standard usage groups for fan motors with similar operating hours are HVAC ventilation supply fans, return fans, and exhaust fans. Examples of standard usage groups to determine lighting operating hours are fixtures with similar operating characteristics in offices, laboratories, hallways, stairwells, common areas, perimeters, storage areas, etc.

Usage groups may be defined for the population on a building-by-building basis or across a number of buildings with similar usage areas. Monitoring can be done for a single or multiple buildings provided the usage groups are similar. Defining populations for multiple buildings is acceptable and usually results in fewer monitoring points than if each building were considered separately.

B.3.3 Select Samples

Select desired confidence and precision levels. A 90/10 confidence/precision level is commonly used in M&V and is suggested.

Establishing the Coefficient of Variation. Prior to selecting a sample, an estimate of the sampled coefficient of variation (C_v) must be made. A C_v of 0.5 has been historically recommended, and numerous projects have shown this to be reasonable guess for most applications. After the first year of monitoring, the coefficient of variation for each usage group can be projected from the results of the metering in the previous year.

Having selected a confidence and precision level (90/10) and a C_v (perhaps 0.5), use Equation 6 and 7, above, to calculate a sample size for each sampling group. Then, randomly select that number of samples from the population. It is strongly recommended that oversampling (at a 10% or greater level) be included in case of data collection device failure or unexpectedly high data scatter.

Table B-1 illustrates the effect of confidence interval and precision on sample size.

Table B-1 First-Year (C_v=0.5) Sample Size Table based on Usage Group Sampling[4]

Precision	20%	20%	10%
Confidence	80%	90%	90%
Z-Statistic	1.282	1.645	1.645
Population Size, N	Sample Size, n*		
4	3	4	4
8	5	6	8
12	6	8	11
16	7	9	13
20	8	10	16
25	8	11	19
30	9	11	21
35	9	12	24
40	9	12	26
45	9	13	28
50	10	13	29
60	10	14	32
70	10	14	35
90	10	15	39
100	10	15	41
125	11	15	45

4 Table does not reflect oversampling. However, because data collection problems are very, very common and because of the departure from normal distribution for small samples (less than 30), over-sampling is critical.

Precision	20%	20%	10%
Confidence	80%	90%	90%
Z-Statistic	1.282	1.645	1.645
Population Size, N	Sample Size, n*		
200	11	16	51
300	11	17	56
400	11	17	59
500	11	17	60
infinite	11	17	68

The samples in each usage group should be drawn at random[5], so that each member has an equal probability of being selected.

If there is reason to believe that there are significant seasonal variations in the operation of the equipment, sufficient monitoring will need to be conducted to capture these variations.

B.4 COLLECT AND ANALYZE SAMPLE DATA

After metering has been completed, calculate mean, standard deviation and C_v (Equation 3) of the collected data for each usage group. If the actual C_v is equal to or less than the C_v originally assumed to calculate the sample size, then the confidence interval will have been met.

Using Equation 1, calculate the maximum error and confidence interval (precision) at the selected confidence level. The confidence interval is then either accepted or, if it is too large, additional sampling (and possible sampling redesign) may be required. Once a sample has been selected and monitoring is done, the engineer has no say over the results, but can rather only report their findings and the level of confidence in the findings.

B.5 EXTRAPOLATE THE RESULT FROM THE SAMPLE OVER THE ENTIRE POPULATION

Once the sample mean and standard deviation are know, the result can be applied to the entire population by assuming the mean of the sample is true for the entire population. For example, if the mean of the sample is Y kW per unit, multiplying the mean of sample by the number of units in the entire population gives the total kW.

Example

Usage group sampling can be applied to one, or numerous, buildings that are similar in function, layout, and operation.

Suppose that an ESCO is retrofitting lighting fixtures in a large office complex containing six buildings that have similar floor plans, functions, and operating schedules. As shown in Table B-2, usage group sampling is applied to each of the four usage groups that appear in the six buildings, and the sample size is 76 points.

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5 Random selection of monitoring points is critical to avoid bias in the sample. Spreadsheet or other computer software should be used to generate a list of random numbers that may be used to place loggers on a given LPC.

Table B-2 Example Inputs for Calculation of Monitoring Sample for Complex A

Usage Groups for Complex A	Number of Lighting LPCs (*N*)							Sample Size (90/20) n^* +10% (rounded)
BUILDING	A-1	A-2	A-3	A-4	A-5	A-6	All	
Offices	400	350	450	440	350	450	2,440	19
Hallways	600	550	450	440	550	450	3,040	19
Meeting Rooms	150	200	200	160	200	200	1,110	19
Other	200	220	180	180	220	180	1,180	19
Total	1,350	1,320	1,280	1,220	1,320	1,280	7,770	76

Note: Sample points (19 for each usage group, as shown above) should be distributed randomly across the sites.

The sampling procedure varies depending on if it is the first monitoring period (no prior sampling data available) or if it is in subsequent monitoring periods:

- ***First Monitoring Period:*** Using Table B-2 or Equations 6 and 7, assuming C_v of the hours = 0.5) to determine the sample size based on number of lighting areas (*N*) in each usage group, one obtains a total sample size of 76, as shown in Table B-3.
- ***Subsequent Monitoring Periods:*** In the second and subsequent years, the same procedure will be used to calculate the sample size, except the actual value of C_v from the data collected in the previous year's sample.

Suppose that the ESCO obtains useful metered data for the required number of sample points and computes the standard errors of the actual measured operating hours for each usage group, where the actual values are presented in Table B-3. Using Equation 1, the standard error of the total estimated savings for each usage group can be calculated. The calculated values are shown in Table B-3. For two of the four usage groups, (hallways and meeting rooms), the actual metered standard error is greater than the allowable amount; thus the reliability requirement is not met for each usage group in the project.

Table B-3 Monitoring Results Based on Usage Group Sampling in the First Performance Period

Usage Groups for Complex A	Number of Samples Metered	Measured Annual Op Hours	Standard Deviation	Maximum Error	Allowable Error	Actual Precision at 90% Confidence	Reliability Requirement Met?
Offices	19	5,256	1,314	495.9	1051.2	9.4%	Yes
Hallways	19	7,008	5,605	2115.3	1401.6	30.2%	No
Meeting Rooms	19	2,628	1,568	591.74	525.6	22.5%	No
Other	19	1,752	701	264.5	350.4	15.1%	Yes
Total	76						

For the subsequent monitoring periods a revised sample size is calculated from the metered data. The actual coefficients of variation (Equation 3) can be calculated from the standard deviation of operating hours in each usage group divided by the average measured hours. These values for C_v are used in Equations 6 and 7 to calculate a revised total sample size and allocation across usage groups. In this example, the revised rounded total sample size is 92. The allocation by usage group is presented in Table B-4.

Table B-4 Revised Sample Requirements Using Usage Group Sampling

Usage Groups for Complex A	N	Original Sample Size	Measured hours	Actual C_v	New Sample Size	New Sample Size n* + 10%
Offices	2,440	19	5,256	0.25	4	5
Hallways	3,040	19	7,008	0.8	43	48
Meeting Rooms	1,110	19	2,628	0.6	24	27
Other	1,180	19	1,752	0.4	11	12
Total	7,770	76				92

B.5 FINAL NOTE

The purpose of sampling is to monitor a representative sample of points rather than the entire population. The end result is to obtain reliable estimates within a specified precision and statistical confidence. Monitoring the specified number of points does not necessarily mean that compliance with project requirements has been obtained. Again, **the job is not done until post-monitoring calculations are completed and reported.**

Sample problems may include improperly designated usage groups, incorrect sample design assumptions, or selection of nonrandom points, all of which may lead to sample-based estimates that are biased and/or unreliable within specified levels. Data logger failure is common, and therefore, over-sampling is usually necessary and recommended. It is critical to take care during the initial developmental stages to design a sample that truly reflects the project site. In any case, the M&V practitioner should use whatever reliable data is available.

C INTERVIEW CONTACTS AND INTERVIEW GUIDES

INTERVIEW CONTACTS

Table C.1 lists the individuals we interviewed for this research.

Table C.1: Interview Contacts

CONTACT	ORGANIZATION
Todd Amundson	BPA (Engineer)
Kacie Bedney	BPA (Engineer)
Eric Boyer	BPA (Engineer)
Jack Callahan	BPA (Engineer)
Craig Ciranny	BPA (Engineer)
Ryan Fedie	BPA (Engineer)
Tom Osborn	BPA (Engineer)
Tim Steele	BPA (Engineer)
Dick Stroh	BPA (Engineer)
Mike Rose	BPA (Contract Administrator)
Karen Meadows	BPA (Energy Services Group)
Lauren Gage	BPA (Evaluation)
Jennifer Eskil	BPA (Program Manager)
Marcus Wilcox	Cascade Energy Engineering
Doug Swier	Cowlitz Public Utility District
Alan Fraser	Eugene Water and Electric Board
Kevin Howerton	Grays Harbor Public Utility District
David Christie	McMinnville Water & Light
Mike Little	Seattle City Light
Jill Steiner	Snohomish PUD
David Harris	Springfield Utility Board
Peter Meyer	Tacoma Power
Tom Eckman	Northwest Power and Conservation Council
Charlie Grist	Northwest Power and Conservation Council

The interview guides used for these various contacts follow. As their name suggests, these instruments were merely guides for the interviews. Actual questions varied from interview to interview as topics of interest arose and were pursued, and as questions were tailored to be appropriate for a given contact.

BPA ENGINEER INTERVIEW GUIDE

Name: ______________________ **Title:** ______________________

Date: ______________________ **Interviewer:** ______________________

Introduction

Role

1. How would you describe your role and responsibilities with [organization] relative to the estimation or use of estimates of energy savings?

2. Has this changed over time? If so, how?

Experience with Protocols

3. With which of the following M&V protocols are you familiar and what is your general usage of them (used them on projects or directed their use on projects, used the results to estimate savings for planning purposes, some other purpose):

   a. 1992 Site Specific Verification guidelines (Blue Book)

   b. Energy Efficiency Implementation Manual (Light M&V Plan) and (M&V Standard)

   c. 2009 Custom Project Completion Report Requirements

   d. RTF Energy Savings Verification Protocols C&RD Appendix P

   e. EWEB Protocols

   f. IPMVP

   g. Other protocols (and under what circumstances were they developed)

4. Which of the following M&V protocols have you used, and for what programs or measures do you typically use each for?

   a. 1992 Site specific Verification guidelines (Blue Book)

   b. Energy Efficiency Implementation Manual (Light M&V Plan) and (M&V Standard)

   c. 2009 Custom Project Completion Report Requirements

   d. RTF Energy Savings Verification Protocols C&RD Appendix P

   e. EWEB Protocols

   f. IPMVP

   g. Other protocols

5. *If not addressed:* Is M&V Light used? When is it used? When is it not used? Why? Does it vary by engineer? Are any projects too small

6. *For each of the following protocols:* What is its purpose? How did it come to be developed?

   a. 1992 Site specific Verification guidelines (Blue Book)

   b. Energy Efficiency Implementation Manual (Light M&V Plan) and (M&V Standard)

   c. 2009 Custom Project Completion Report Requirements

   d. RTF Energy Savings Verification Protocols C&RD Appendix P

   e. EWEB Protocols

7. To date, what precision and confidence levels have you expected or desired for the results produced following these M&V protocols? [*Probe if varies by protocol*]

   a. What is the basis for desired accuracy level?

   b. Do you feel the reported results have met those levels?

   c. How often are "error bands" or confidence intervals reported with the results? (e.g., +/- 10%)

   d. How do you determine overall accuracy of results?

8. Going forward, will the protocols need to serve any new purposes, or will the results be used or compiled and analyzed to any new purpose? *Probe:* How are the engineers thinking about protocols relative to the new industrial program?

   a. What precision and confidence levels would you suggest or what factors should go into making such a determination?

   b. What are your views on project risk—from the perspectives of end user, your customer utilities, and BPA—that the protocols should be designed to minimize?

   c. And what are your views on the costs imposed by M&V—on the end user, utility, and BPA—that the protocols should also be designed to minimize?

9. For those who have used for projects: What has been your **experience** using these protocols on projects? [Discuss each protocol individually. Probe for:]

   a. How easy or straightforward has it been to implement the [specific] protocol? Was any difficulty encountered in implementing the protocol? If so, what difficulty?

   b. Are you aware of situations where the protocol was not implemented as prescribed? If so, please describe them. [*Probe:*] Why did that occur? What was the result?

   c. Have you found the protocol to provide value for end use customers?

   d. Please describe how long you do pre-installation data collection (the answer should vary by measure)

   e. Please describe how long you do post-installation data collection (the answer should vary by measure)

10. Were there any specific concerns that the protocols were not accomplishing their intended purpose? If so, what concerns?

11. Is there any way to reduce the amount of time it takes to review projects?

12. Did you feel the protocols lead to valid and reliable results?

   a. If not, are there shortcomings in the protocols themselves, or in their application?

   b. What specific examples are there of these shortcomings?

13. *For those with protocol project experience:* Are there particular situations in which the protocols are more effective?

    a. Are there particular situations in which the protocols are not as effective as desired or not seen as appropriate? If so, what were those situations? What was done in such situations?

    b. Are there any measures or applications that do not fit the existing protocols?

    c. If so, what are those measures or applications, and what has been your experience with attempts to use the protocols for them?

14. If your goals doubled or tripled what changes would need to be made? *Probe:* More staff? Use contractors?

Documentation

15. *For those who review or use the results of the protocols*: How were the results of the application of the protocols documented?

    a. Was any documentation (typically) missing? What documentation was unnecessary, if any?

    b. Are you comfortable with the level of documentation produced? If not, what changes are needed?

16. *For those who do the project specific protocol application*: Do you have any difficulties meeting the requirements for documentation?

    a. What specific problems and in what type of situations?

    b. Any way the documentation could be improved?

Protocol Implementation Guidance

17. Have there been any indications of a need for increased guidance or more description of steps to implement the protocols?

18. In BPA's current efforts to update the M&V protocols, what sorts of updates would you like to see? [*Probes:* Updates in subject area? In rigor? In explanation?]

19. Do you have any opinions about the tradeoffs between assuring savings through M&V of projects, versus through an evaluation of program savings across multiple projects?

20. How concerned are you about the issue of free-ridership?

Tools and Data

21. Are you aware of any tools or algorithms or savings calculators that are useful in estimating custom project savings? If so, what? Could you send us a copy?

    a. Any data sources? If so, what?

    b. Are these tools still in use in the efficiency community? Are the data sets still current?

22. Do these tools require training time? If so, how much training and time? How does this affect projects?

23. Are outside experts required to use these tools? If so, how does that limit their applicability?

24. Does the cost of the tools affect their use? If so, in what way?

25. Do you have any ideas for tools and/or data sources? *Probe:* Which engineers have developed their own deemed savings calculators, and what are the calculators?

Summary

26. What would you say are the greatest strengths of the each of the protocols with which you are familiar?

27. What are the most important improvements that could be made to them?

28. How do you recommend that BPA and any of its customer utilities might stay abreast of M&V developments? Groups to join?

29. What would you most like to learn from this M&V update in which BPA is engaged?

UTILITY INTERVIEW GUIDE

Name: ______________________ **Org:** ______________________

Date: ______________________ **Interviewer:** ______________________

Introduction

Role

1. How would you describe your role and responsibilities with [organization] relative to the estimation or use of estimates of energy savings?

2. Has this changed over time? If so, how?

Experience with Protocols

3. With which of the following M&V protocols are you familiar and what is your general usage of them (used them on projects or directed their use on projects, used the results to estimate savings for planning purposes, some other purpose):

   a. 1992 Site Specific Verification guidelines (Blue Book)

   b. Energy Efficiency Implementation Manual (Light M&V Plan) and (M&V Standard)

   c. 2009 Custom Project Completion Report Requirements

   d. RTF Energy Savings Verification Protocols C&RD Appendix P (compressed air)

   e. EWEB Protocols

   f. IPMVP

   g. Other protocols (and under what circumstances were they developed)

4. Which of the following M&V protocols have you used, and for what programs or measures do you typically use each for?

   a. 1992 Site specific Verification guidelines (Blue Book)

   b. Energy Efficiency Implementation Manual (Light M&V Plan) and (M&V Standard)

   c. 2009 Custom Project Completion Report Requirements

   d. RTF Energy Savings Verification Protocols C&RD Appendix P

   e. EWEB Protocols

   f. IPMVP

   g. Other protocols

5. For those who have used for projects: What has been your **experience** using these protocols on projects? [Discuss each protocol individually. Probe for:]

   a. How easy or straightforward has it been to implement the [specific] protocol? Was any difficulty encountered in implementing the protocol? If so, what difficulty?

   b. Are you aware of situations where the protocol was not implemented as prescribed? If so, please describe them. [*Probe:*] Why did that occur? What was the result?

   c. Have you found the protocol to provide value for end use customers?

   d. Please describe how long you do pre-installation data collection (the answer should vary by measure)

   e. Please describe how long you do post-installation data collection (the answer should vary by measure)

6. Were there any specific concerns that the protocols were not accomplishing their intended purpose? If so, what concerns?

7. Did you feel the protocols lead to valid and reliable results?

   a. If not, are there shortcomings in the protocols themselves, or in their application?

   b. What specific examples are there of these shortcomings?

8. *For those with protocol project experience:* Are there particular situations in which the protocols are more effective?

   a. Are there particular situations in which the protocols are not as effective as desired or not seen as appropriate? If so, what were those situations? What was done in such situations?

   b. Are there any measures or applications that do not fit the existing protocols?

   c. If so, what are those measures or applications, and what has been your experience with attempts to use the protocols for them?

Documentation

9. *For those who review or use the results of the protocols*: How were the results of the application of the protocols documented?

   a. Was any documentation (typically) missing? What documentation was unnecessary, if any?

   b. Are you comfortable with the level of documentation produced? If not, what changes are needed?

10. *For those who do the project specific protocol application*: do you have any difficulties meeting the requirements for documentation?

    a. What specific problems and in what type of situations?

    b. Any way the documentation could be improved?

Protocol Implementation Guidance

11. In BPA's current efforts to update the M&V protocols, what sorts of updates would you like to see? [*Probes*: Updates in subject area? In rigor? In explanation?]

12. Do you have any opinions about the tradeoffs between assuring savings through M&V of projects, versus an impact evaluation of program savings across multiple projects?

13. How concerned are you about the issue of free-ridership?

Tools and Data

14. Are you aware of any tools or algorithms or savings calculators that are useful in estimating custom project savings? If so, what?

    a. Any data sources? If so, what?

    b. Are these tools still in use in the efficiency community? Are the data sets still current?

15. Do these tools require training time? If so, how much training and time? How does this affect projects?

16. Are outside experts required to use these tools? If so, how does that limit their applicability?

17. Does the cost of the tools affect their use? If so, in what way?

18. Do you have any ideas for tools and/or data sources?

Summary

19. What would you say are the greatest strengths of the each of the protocols with which you are familiar?

20. What are the most important improvements that could be made to them?

21. How do you recommend that BPA and any of its customer utilities might stay abreast of M&V developments? Groups to join?

22. What would you most like to learn from this M&V update in which BPA is engaged?

NWPCC INTERVIEW GUIDE

Name: ______________________________ **Title:** ______________________________

Date: ______________________________ **Interviewer:** ______________________________

Introduction

Role

1. How would you describe your role and responsibilities with [organization] relative to the estimation or use of estimates of energy savings?

2. Has this changed over time? If so, how?

Experience with Protocols

3. With which of the following M&V protocols are you familiar and what is your general usage of them (used them on projects or directed their use on projects, used the results to estimate savings for planning purposes, some other purpose):

   a. 1992 Site Specific Verification guidelines (Blue Book)

   b. Energy Efficiency Implementation Manual (Light M&V Plan) and (M&V Standard)

   c. 2009 Custom Project Completion Report Requirements

   d. RTF Energy Savings Verification Protocols C&RD Appendix P (compressed air)

   e. EWEB Protocols

   f. IPMVP

   g. Other protocols (and under what circumstances were they developed)

4. *For each BPA protocol familiar with:* What is its purpose? How did it come to be developed?

    a. 1992 Site specific Verification guidelines (Blue Book)

    b. Energy Efficiency Implementation Manual (Light M&V Plan) and (M&V Standard)

    c. 2009 Custom Project Completion Report Requirements

    d. RTF Energy Savings Verification Protocols C&RD Appendix P (compressed air)

    e. EWEB Protocols

5. To date, what precision and confidence levels have you expected or desired for the results produced following these M&V protocols? [*Probe if varies by protocol*]

    a. What is the basis for desired accuracy level?

    b. Do you feel the reported results have met those levels?

    c. How often are “error bands” or confidence intervals reported with the results? (e.g., +/- 10%)

    d. How do you determine overall accuracy of results?

6. Going forward, will the protocols need to serve any new purposes, or will the results be used or compiled and analyzed to any new purpose?

    a. What precision and confidence levels would you suggest or what factors should go into making such a determination?

    b. What are your views on project risk—from the perspectives of end user, your customer utilities, and BPA—that the protocols should be designed to minimize?

    c. And what are your views on the costs imposed by M&V—on the end user, utility, and BPA—that the protocols should also be designed to minimize?

7. Have you had any specific concerns that the protocols were not accomplishing their intended purpose? If so, what concerns?

8. Did you feel the protocols lead to valid and reliable results?

   a. If not, are there shortcomings in the protocols themselves, or in their application?

   b. What specific examples are there of these shortcomings?

9. Are there particular situations in which the protocols are more effective?

   a. Are there particular situations in which the protocols are not as effective as desired or not seen as appropriate? If so, what were those situations? What was done in such situations?

   b. Are there any measures or applications that do not fit the existing protocols?

   c. If so, what are those measures or applications, and what has been your experience with attempts to use the protocols for them?

Documentation

10. *For those who review or use the results of the protocols*: How were the results of the application of the protocols documented?

    a. Was any documentation (typically) missing? What documentation was unnecessary, if any?

    b. Are you comfortable with the level of documentation produced? If not, what changes are needed?

11. *For those who do the project specific protocol application*: do you have any difficulties meeting the requirements for documentation?

    a. What specific problems and in what type of situations?

    b. Any way the documentation could be improved?

Protocol Implementation Guidance

12. Do you have any opinions about the tradeoffs between assuring savings through M&V of projects, versus through an evaluation of program savings across multiple projects?

13. How concerned are you about the issue of free-ridership?

Tools and Data

14. Are there deemed savings calculators not yet incorporated by the RTF that BPA should consider using or developing? Suggested data sources for such development?

Summary

15. What would you say are the greatest strengths of the each of the protocols with which you are familiar?

16. What are the most important improvements that could be made to them?

17. How do you recommend that BPA and any of its customer utilities might stay abreast of M&V developments? Groups to join?